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THESIS

FINANCIAL ANALYSIS OF HASTILY FORMED NETWORKS

by

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September 2006

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13. ABSTRACT (maximum 200 words)

One of the common lessons learned from the 11 September Terrorist Attacks in 2001, Southeast Asia Tsunami in 2004 and Hurricane Katrina in 2005, was there were major command and control (C2) and information challenges during the crisis response efforts. The Department of Defense (DoD) is currently transitioning to face these global threats of terrorism and natural disasters, as well as support the goals of the new National Strategy, by developing new plans and procedures to improve the coordination, communications and operations between DoD and other entities when responding simultaneously to such complex humanitarian disasters (CHD). In searching for a mobile and adoptable communication solution for military operations, the DoD should consider a C2 system that utilizes advanced commercial-off-the-shelf (COTS) technology. Hastily-formed networks (HFN) could provide a global broadband network node with internet, voice, video and data capability in a rapidly deployable manner, which offer significant advantages to military and other crisis response activities. The focus of this thesis concentrates on the financial aspects of HFNs in support of humanitarian assistance and/or disaster relief (HA/DR) efforts by U.S. armed forces. This research and analysis of HFNs could present prospective benefits to DoD, which include cost-savings, enhanced emergency response capabilities and improved interagency/international relations. Additionally, this study will provide a recommended model methodology and iterations for future military-use of HFNs in support of the DoD's vision of "transformation."

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FINANCIAL ANALYSIS OF HASTILY FORMED NETWORKS

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ABSTRACT

One of the common lessons learned from the 11 September Terrorist Attacks in 2001, Southeast Asia Tsunami in 2004 and Hurricane Katrina in 2005, was there were major command and control (C2) and information challenges during the crisis response efforts. The Department of Defense (DoD) is currently transitioning to face these global threats of terrorism and natural disasters, as well as support the goals of the new National Strategy, by developing new plans and procedures to improve the coordination, communications and operations between DoD and other entities when responding simultaneously to such complex humanitarian disasters (CHD). In searching for a mobile and adoptable communication solution for military operations, the DoD should consider a C2 system that utilizes advanced commercial-off-the-shelf (COTS) technology. Hastily-formed networks (HFN) could provide a global broadband network node with internet, voice, video and data capability in a rapidly deployable manner, which offer significant advantages to military and other crisis response activities. The focus of this thesis concentrates on the financial aspects of HFNs in support of humanitarian assistance and/or disaster relief (HA/DR) efforts by U.S. armed forces. This research and analysis of HFNs could present prospective benefits to DoD, which include cost-savings, enhanced emergency response capabilities and improved interagency/international relations. Additionally, this study will provide a recommended model methodology and iterations for future military-use of HFNs in support of the DoD's vision of "transformation."

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Thank you, Jennifer, Jared and Erin Runaas.

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LIST OF ABBREVIATIONS / ACRONYMS

AFCS	Autonomous Flight Control System
ALS	Advanced Life Support
AMR	American Medical Response Inc.
AO	Area of Operations
AP	Access Point
BLS	Basic Life Support
BS	Base Station
C2	Command and Control
C4ISR	Command, Control, Computers, and Communications for Intelligence, Surveillance and Reconnaissance
CAD	Computer-Aided Dispatch
CCU	Critical Care Unit
CFR	Certified First Responder
CGOES	California Governor's Office of Emergency Services
CHD	Complex Humanitarian Disaster
CNO	Chief of Naval Operations
CNSP	Commander Naval Surface Forces, Pacific Fleet
COASTS	Coalition Operating Area Surveillance and Targeting System
COMPACFLT	U.S. Commander Pacific Fleet
CONUS	Contiguous United States
COTS	Commercial-off-the-shelf
CSG	Carrier Strike Group

DoD	Department of Defense
DRDO	Defense Research Development Organization
EMT	Emergency Medical Technician
ESG	Expeditionary Strike Group
FEMA	Federal Emergency Management Agency
FHL	Fort Hunter-Ligget
FISC	Fleet and Industrial Supply Center
FLAK	Fly-away-kit
GB	Gigabyte
GF	Grayback Forestry Co.
GGSN	Golden Gate Safety Network
GHz	Gigahertz
GPS	Global Positioning System
GWOT	Global War on Terrorism
HA/DR	Humanitarian Assistance and/or Disaster Relief
HCA	Head of Contracting Activity
HFN	Hastily-formed Networks
IEEE	Institute of Electrical and Electronics Engineers
IIFC	Inter-agency Intelligence and Fusion center
ILS	Intermediate Life Support
IM	Instant Messaging
IP	Internet Protocol
ISR	Intelligence, Surveillance and Reconnaissance
IT	Information Technology

JIATF-W	Joint Interagency Task Force West
JUSMAGTHAI	Joint United States Military Advisory Group Thailand
KA	Knowledge Allocation
KVA	Knowledge Value Added/Analysis
LAN	Local Area Network
LFA	Lead Federal Agency
LOS	Line of Sight
LT	Learning Time
MD	Mesh Dynamics
MICU	Mobile Intensive Care Unit
MOE	Measures of Effectiveness
MOOTW	Military Operations Other Than War
MOP	Measures of Performance
NAVSUP	Naval Supply Systems Command
NOC	Network Operations Center
NGO	Non-governmental Organizations
NLOS	Non-line of Sight
NPS	Naval Postgraduate School
OEF	Operation Enduring Freedom
OES	Office of Emergency Services
OIF	Operation Iraqi Freedom
OMB	Office of Management and Budget
OSD	Office of the Secretary of Defense
PAN	Portable Area Network

PDA	Personal Digital Assistant
PPBE	Planning, Programming, Budgeting and Execution
PtMP	Point to Multi-point
PTZ	Pan Tilt Zoom
PUK	Pack-up Kit
QDR	Quadrennial Defense Report
QoS	Quality of Service
R&D	Research and Development
ROI	Return on Investments
ROK	Return on Knowledge
ROP	Return on Process
RTA	Royal Thai Army
RTAF	Royal Thai Air Force
RV	Recreational Vehicle
SME	Subject Matter Expert
SMC	Systems Management Console
SOSUS	Sound Surveillance System
TNT	Tactical Network Topology
TOC	Tactical Operation Center
TYCOM	Type Commanders
UAV	Unmanned Aerial Vehicle
UPS	Uninterruptible Power Supply
U.S.	United States
USCG	United States Coast Guard

USN	United States Navy
USMC	United States Marine Corps
USPACOM	United States Pacific Command
USSOCOM	United States Special Operations Command
UAV	Unmanned Aerial Vehicle
VTOL	Vertical Take-off and Land
VPN	Virtual Private Network
WLAN	Wireless Local Area Network
WAN	Wide Area Network
WAP	Wireless Access Point
WiMax	Worldwide Interoperability for Microwave Access

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I. INTRODUCTION

> As we prepare for the future, we must think differently and develop the kinds of forces and capabilities that can adapt quickly to new challenges and to unexpected circumstances. We must transform not only the capabilities at our disposal, but also the way we think, the way we train, the way we exercise and the way we fight. We must transform not only our armed forces, but also the Department that serves them by encouraging a culture of creativity and prudent risk-taking. We must promote an entrepreneurial approach to developing military capabilities, one that encourages people to be proactive, not reactive, and anticipates threats before they emerge.[1]
>
> - Donald H. Rumsfeld, Secretary of Defense

A. PURPOSE

The purpose of this thesis is to analyze the financial aspects of hastily-formed networks (HFNs), when utilized as a communications solution for humanitarian assistance and/or disaster relief (HA/DR) operations involving U.S. armed forces. Additionally, this thesis will provide a recommended model methodology and iterations for future military-use of HFNs in support of "transformation," as defined by the Department of Defense (DoD).

During the relief efforts of the 11 September 2001 Terrorist Attacks (9/11), December 2004 Southeast Asia Tsunami and August 2005 Hurricane Katrina, there were major command and control (C2) and information challenges for the various multi-agency responders. The DoD and Non-Government Organizations (NGOs) abroad are currently dealing with these challenges to develop new plans and procedures to improve the security and communication processes of the United States and their allies.

Increasingly, National interests are focusing on improvements in coordination, communications and operations between the DoD and other entities when responding simultaneously to natural or man-made Complex Humanitarian Disasters (CHDs). Although there have been tremendous technology advancements, it is still very difficult to set up, manage, and interact with networked devices. An effective HFN could provide

[1] Foreword from Secretary of Defense, Donald H. Rumsfeld, *Transformation Planning Guidance*, 2003.

a global broadband network node with internet, voice, video and data capability in a rapidly deployable manner. These C2 capabilities easily provide significant advantages to military activities, NGOs and the private sector. A financial analysis of HFNs could present prospective benefits to DoD, which include cost-savings, enhanced emergency response capabilities and improved interagency/international relations.

B. BACKGROUND

Increased terrorist threats and post-9/11 national and international CHDs, appear to have had a direct effect on the conduct of our nation. The fact that many of these events are occurring on U.S. soil emphasizes the need for greater awareness, more thorough cross communication and significant changes in our National Defense and National Military Strategy. Although C2 and information requirements for DOD and NGOs are rapidly changing within this new environment, the utilization of information as a strategic resource remains an unchanged requirement.

As far back as the Revolutionary War, the U.S. military has continued to leverage information as a strategic resource. Advanced information technology (IT) systems have improved the way information is communicated. As U.S. forces decrease in size, there will be a need for a higher degree of mobility and sustainability. Furthermore, the DoD must continue exploring the applications and financial implications of IT solutions that focus on improving all service branch's ability to operate as a joint force. Early transformation requires exploiting IT opportunities to reform defense business practices and to create new combinations of capabilities, operating concepts, organizational relationships and training regimes.[2]

C. RESEARCH QUESTIONS

In order to determine whether the concepts of market comparables and KVA can be effectively applied to the DoD and its vision of transformation, the following research questions need to be answered:

- What are the financial implications using HFNs in a remote or devastated operating area?
- What benefits can be gained by using the Knowledge Value Analysis (KVA) on Hastily-formed Networks (HFNs) in support of Humanitarian Assistance/Disaster Relief (HA/DR) Operations?

[2] *Transformation Planning Guidance*, United States Department of Defense [US DoD], 2003.

- How can we use the Market Comparables approach to estimate or monetize the revenue component to a similar civilian organization (Western wild fires, Hurricane Katrina, etc.)?
- What are equivalent market comparables for financial implications to the DOD/NGO HA/DR functions?

D. SCOPE

This thesis will cover the conceptual aspects of the definition and application of HFNs in military-use for HA/DR operations. Through an in-depth research of HFN equipment and review of the current industry literature on market comparables and KVA, this thesis will integrate the two and determine the benefits of implementing this prospective C2 initiative. Another focus of this research will be developing a model and methodology for future HFNs and exploring the funding and implementation process.

Data will be collected from the Coalition Operating Area Surveillance and Targeting System (COASTS) project. The COASTS project expands the NPS Monterey Research and Development (R&D) partnership with Thailand and supports the objectives of U.S. Pacific Command (USPACOM), which include Regional Maritime Security, Theater Security Cooperation and War on Terror campaign. Additional data will be collected from another commercial IT solution tested during a Homeland Security field exercise, involving various multi-agency responders.

Prospective benefits of this research include the following:

1. Joint research project
    a. Cost-effectiveness: leveraging both U.S. and Thailand expertise and technology
2. Long-term investment
    a. Systematic and Spiral Development research program
    b. Provisions for future opportunities
3. Information-sharing among participants
    a. U.S. & Thailand science and technology stimulation
4. Financial implications in the deployment of HFNs
    a. HA/DR
    b. Remote operating locations

E. METHODOLOGY

The methodology for this thesis research includes the following steps:

1. Conduct a comprehensive literature search of books, journal articles and Internet based materials.
2. Conduct a comprehensive review of government reports concerning force structure initiatives, optimization efforts and DOD Directives regarding transformation from a business process perspective.
3. Conduct necessary interviews to acquire critical insight and understanding of current government policy governing the roles of HA/DR.
4. Develop a model and methodology for future HFNs that will incorporate the following:
    a. Market Comparables
    b. KVA application
    c. Scalable limitations

F. ORGANIZATION

This thesis research will be organized in the following manner:

- CHAPTER I: INTRODUCTION – consisting of an outline and overview of this thesis research, it will include purpose, background, scope, methodology and organization.
- CHAPTER II: HFN TECHNOLOGIES – will consist of a description and overview of HFNs, as well as an introduction and overview of HFN components and equipment.
- CHAPTER III: DATA COLLECTION – will consist of data collected from three field experiments: 1) COASTS Point Sur testing; 2) COASTS Thailand testing; and 3) Homeland Security testing (a comparable C2 application).
- CHAPTER IV: FINANCIAL OPPORTUNITIES – will consist of a description and overview of the market comparables and KVA concept and its potential applications. This will include a discussion of the concept of market comparables and KVA in the context of HA/DR operations. Additional data will be findings from the financial methodologies, which will include two guidelines business selections and KVA calculations.
- CHAPTER V: ANALYSIS – will consist of the analysis of the data collections from Chapter IV. Further analysis will focus on model methodology, prospective implementation, optional iterations and scalable limitations. This is intended to solidify the premise that HFNs can be

- successfully utilized as a C2 solution for military-use during HA/DR operations and serve as a launching platform for responsible, effective transformation efforts.
- CHAPTER VI: CONCLUSION AND RECOMMENDATIONS – will summarize the efforts of this research, solidify conclusions and make recommendations about where future research can expand on these efforts.

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II. HFN TECHNOLOGIES

A. WHAT IS AN HFN

With current technology, our society lives in a networked world where people can communicate digitally, using a wide variety of means that include telephones, email, instant messaging and video/web-hosted conferencing. As technology advances and communication costs decline, the general public will continue to communicate, collaborate and cooperate even more.[3] Machines have many ways to talk to one another. They enable people to make things happen more quickly, more effectively and across greater distances. Machines can request services of one another or allow others to access their services and accomplish work remotely. Furthermore, they share information and databases, which are often distributed among sub-databases and replicated to assure high availability in multiple locations. Network protocols exist for allowing our machines to interact and operate wired or wireless. In a matter of just a few years, there will be more devices communicating with one another than there are people on earth.[4] Opportunities abound to use this advanced and cheaper technology for national and humanitarian interests.

The Department of Defense (DoD) and the Naval Post Graduate School (NPS) established the term hastily-formed network (HFN), which describes the combined actions of people in a network of multi-organizational groups, with no common authority, that collaborate to create coordinated action in crises.[5] Such crisis can be a man-made disaster (9/11 attacks), a natural disaster (2005 Indonesia Tsunami and Hurricane Katrina) or an urgent operational/business necessity. The following are characteristics of situations where an HFN may be necessary:

- Genuine surprise: Advance planning, training or positioning of equipment has not been prepared for the unexpected event.
- Chaos: People are frantic, panicked, overwhelmed and confused.

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[3] Dr. Rick Hayes-Roth, Hyper-Beings: How Intelligent Organizations Attain Supremacy through Information Superiority, 10-11, 2003.

[4] Ibid

[5] Clanon, Jeff . "SoL's Hastily Formed Networks Project." Society for Organizational Learning. Society for Organizational Learning. 18 Sep 2006 <www.solonline.org>.

- Insufficient resources: Magnitude of the event overwhelms available resources.
- Multi-agency response: Military, civilian government and/or private organizations are compelled collaborate, regardless of any lack of past teamwork experience.
- Distributed response: The response is distributed over a geographical area into many local jurisdictions.
- Lack of infrastructure: Infrastructures that provide communications, electricity and water will most likely not be operational.[6]

For the purpose of cooperative collaboration, many view HFNs as a system that combines advanced networking technology and human organization issues. Peter J. Denning argues that HFN's are much more than a set of organizations using advanced networking technology.[7] According to Denning, an HFN has five elements: (1) a network of people established rapidly (2) from different communities, (3) working together in a shared conversation space (4) in which they plan, commit to, and execute actions, to (5) fulfill a large, urgent mission.[8] The broader concern is how to use these elements to respond to a crisis.

B. HOW IS AN HFN USED

After an unexpected disaster or event, one of the highest priorities of the first responders is to establish operative communications among involved agencies because it is a fundamental principle for successful planning and response to crisis situations.[9] An effective communication system can provide the responders with critical information, which allows them to pool their knowledge and interpretations of the situation, understand what resources are available, assess options, plan responses, decide, commit, act and coordinate. Without such a communication system, more than likely these actions may not happen and the responders may not function as effectively.[10] An HFN

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[6] Chad Runge. "Disaster Relief Efforts & Information." Hastily Built Network to Deploy to Gulf Region . 09 SEP 2005. Naval Postgraduate School. 18 Sep 2006 <http://www.nps.navy.mil/DisasterRelief/Katrina/news/20050909.htm>.

[7] Peter J. Denning, "The Profession of IT," *Communications of the ACM*, Vol. 49, No. 4, April 2006.

[8] Ibid

[9] DHS Comprehensive Reviews Fact Sheet document, "Comprehensive Reviews Yield Effective Practices for Homeland Security," U.S. Department of Homeland Security, 30 MAR 2006.

[10] Peter J. Denning, "The Profession of IT," *Communications of the ACM*, Vol. 49, No. 4, April 2006.

used for HA/DR operations must (1) exist in an unclassified realm, (2) be operated by skilled and trained personnel and (3) have the appropriate components that satisfy the requirements.

For the purposes of facilitating a collaborative environment between the military and NGOs, it is recommended for the HFN to be operated in an unclassified realm to support all users, deal with multiple connection types which include mesh enabled clients and support disadvantaged users to include sensors. A HA/DR environment will most likely involve large number of personnel, from various organizations, attempting to sort out and manage the information flow. Since the necessity for people to have network availability and share information is the root essence of an HFN, it is important that all applicable responders have access to the information. Furthermore, if the commercial industry dominates the technological direction for HFNs, then the network will simply be unclassified by nature of the manufactured devices.[11] Of course, there is the important concern of information assurance. Although the general mission for HA/DR evolutions is to help people, security measures that support information assurance must still be practiced and enforced. Unclassified information, that is both accessible to the right people and properly secured to protect validity, is essential for successful HA/DR operations.

In addition to an unclassified realm, the responders to the crisis must also be trained to operate and understand the equipment of the HFN and comprehend the rules and protocols of dealing with HA/DR situations nationally and internationally. To be effective in action, HFN participants must be skilled at:[12]

- Setting up mobile communication and sensor systems.
- Conducting interagency operations; also known as "civil-military boundary."
- Collaborating on action plans and coordinating their execution.
- Leading a social network (where communication and decision-making are decentralized and there is no hierarchical chain of command).
- Improvising.

[11] David D. Lancaster, "Developing a Fly-away-kit to Support HFNs for HA/DR," June 2005.

[12] Denning

Since most participants do not have a need for these skills in their individual organizations, there tends to be difficulty to accomplish these tasks when a crisis brings applicable organizations together. When combined with the overwhelming nature of the urgent event, these inherent difficulties can lead to a breakdown in the communication system and the ways they interact within it.[13] This is why organizations typically involved with HA/DR operations must properly train their response units to understand and operate HFN equipment. After responders learn how to use HFNs, they must be able to trust and collaborate with other organizations involved with the operation. Before dwelling into the trust and collaboration matter, participants must next ensure the HFN actually works.

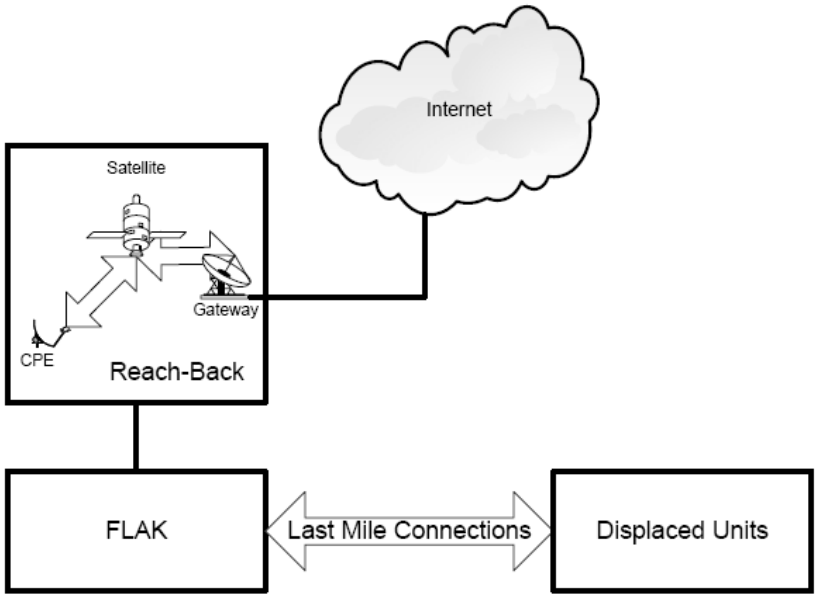

Figure 1. HFN Components (From Lancaster)

In order to properly function in action, an HFN must have the appropriate components that satisfy the requirements of operating in a HA/DR situation. There are three main components that meet the requirements for an HFN:[14]

1) Back-haul connection is the main connection that links a remote site to the rest of the world. The remote terminating end of the back-haul is normally referred to as a point of presence. An example of a back-haul connection is a commercial satellite connected to the internet or possibly a

[13] Peter J. Denning, "The Profession of IT," *Communications of the ACM*, Vol. 49, No. 4, April 2006.

[14] David D. Lancaster, "Developing a Fly-away-kit to Support HFNs for HA/DR," June 2005.

headquarters facility. Commercial satellites meet the mobility and availability requirements of a HA/DR HFN. Other solutions include terrestrial fiber, serial or DSL connections.

2) Last mile connections are links from the point of presence to displaced units throughout the area of operations. The purpose of these connections is to maximize use of the broadband connection to the point of presence device, particularly because of limitations of the displaced units. Due to the flexible and transportable requirements of an HFN, most solutions for last mile connectivity are wireless. Example solutions include free-space optics, IEEE 802.11 WiFi and IEEE 802.16 WiMAX.

3) Connecting network devices support the flexible connections between the back-haul solution and the last-mile solution. This collection of equipment acts as the point of presence node. The purpose of these devices is to ensure the HFN is mobile and capable of supporting multiple connections and applications. Ethernet is the recommended interconnectivity with other devices. An example solution is a Fly-away-kit (FLAK). A FLAK should be self contained, rugged, transportable and contain everything essential to supporting operations at an alternate site.

The success of an effective HFN is based on how well networking technologies, sensor systems, autonomous coordination, human communication, improvisation, organizational theory and trust is incorporated in the communication system.[15]

C. INTRODUCTION OF HFN EQUIPMENT USED

For 2006, COASTS intended to provide a robust IEEE 802.11 wireless mesh network to enable seamless network connectivity for sensor, UAV and mobile client operations throughout the AOR.

1. 802.11

The IEEE 802.11 equipment chosen for COASTS 2006 are the Mesh Dynamics multiradio back-haul access points. The reason for selecting Mesh Dynamics is the advertised improved bandwidth over single-radio implementations of mesh networks, their ability to withstand and perform in austere environmental conditions, and their form factor. According to Mesh Dynamics a single-radio unit uses the same radio to both send and receive which cannot be accomplished simultaneously. The access points (nodes) listen then retransmit. Also, all nodes operate on the same channel which, depending on the topology, causes a 50% bandwidth loss for each hop.

[15] Chad Runge. "Disaster Relief Efforts & Information." Hastily Built Network to Deploy to Gulf Region . 09 SEP 2005. Naval Postgraduate School. 18 Sep 2006 <http://www.nps.navy.mil/DisasterRelief/Katrina/news/20050909.htm>.

Two mesh architectures are shown in Figure 2 below. Most mesh products are a variant of the approach shown on the left. One radio services clients (pink) while the other radio (blue) forms a single radio ad hoc back-haul mesh. The radios operate in non interfering bands: 2.4 GHz (pink) for service and 5.8 GHz (blue) for the back-haul. Note that the wireless back-haul is still a single radio - only one radio (blue) is part of the back-haul. Packets share bandwidth at each hop along the path with other interfering mesh back-hauls - all operating on the same channel - because it is a single radio wireless back-haul.

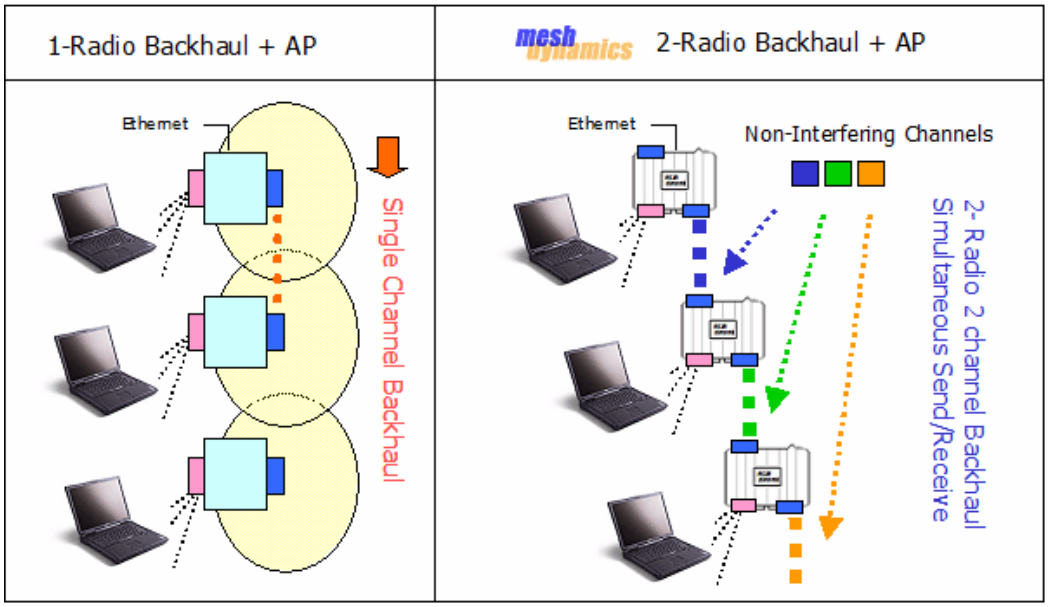

Figure 2. MeshDynamics multi-radio back-haul Simultaneous Send and Receive (From: F. Acosta)

MeshDynamics Mesh Products have two back-haul radios (for uplink/downlink) and a third 2.4GHz service radio. The back-haul up link and down link "talk" on different channels. Bandwidth degradation effects endemic to single radio back-hauls are eliminated - each radio link operates independently and simultaneous send/receives are now possible. The separate uplink and downlink emulates wired switch stacks. This architecture supports scalable networks. Minimal performance degradation is experienced, even over several WAP segments.

In the unlicensed space, interference from other radios is a fact of life. Reduced performance by operating on a "polluted" channel is especially significant in dense metro

areas. In 1-radio back-hauls all radios share the same channel. Interference on that channel affects the entire network. In contrast, a 2-radio back-haul is more agile: the back-haul radios can switch to other channels to mitigate local interference sources.

The MeshDynamics Modular Mesh framework is purpose built to ensure interoperability between members of the product family. Modules form a network even if back-haul operate in different frequency bands.

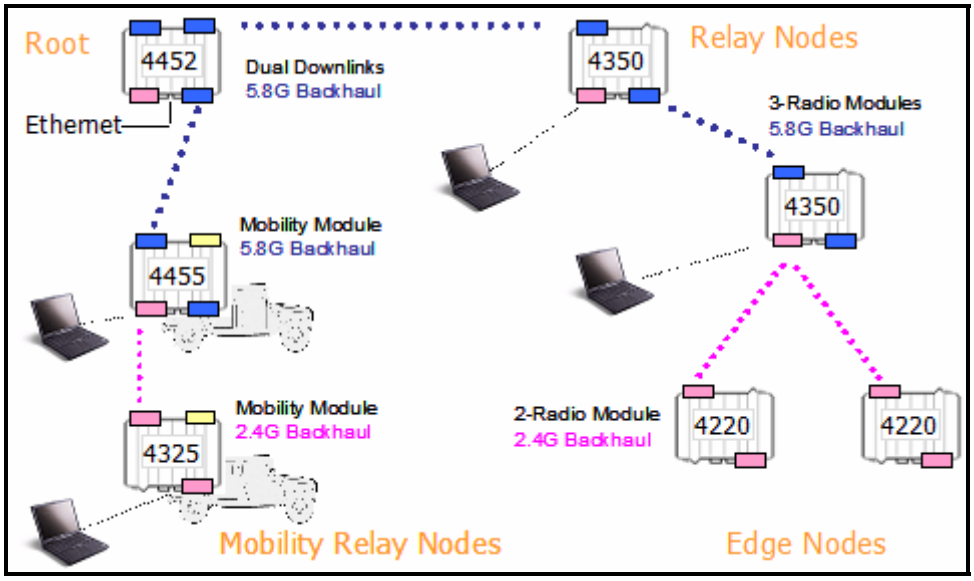

Figure 3. Modular Mesh Interoperable Network (From: F. Acosta)

As an example (See Figure 3), the two mobile nodes above communicate with each other, though they are operating on different back-haul bands. The "service" radio of node 4455 is acting as the parent downlink for node 4325. Also edge nodes 4220 connects with relay node 4350 through the service radio.

Since 2.4GHz has more range than 5.8GHz radios, a 2.4GHz back-haul is preferable in low client density situations (such as rural areas) or at edges of the network where the interference is low. Interference increases with increasing client densities (as in urban areas). The 2.4GHz edge node (4220) does not become obsolete: it may be field upgraded to a 3-Radio 5.8GHz back-haul + AP (4350). The 4350 unit may be field

upgraded to a 4-radio module if additional downlinks (4452) or an additional AP (4458) is needed. Other mesh products have not been designed with this level of flexibility in mind.[16]

Due to the stated strengths of the Modular Mesh system, it was selected for implementation by the COASTS 2006 project. As such, and to maintain interoperability within the mesh, a MD mobile access point was selected as the 802.11 Wireless Access Point (WAP) payload for the VTOL UAV surrogate.

The Mesh Dynamics access points are highly configurable allowing varying radio powers, operating frequencies, in the IEEE 802.11 a/b/g standards, and software configurations to suit specific applications. COASTS 2006 will employ the device configurations listed in Table 3.

Model	**Specifications**
MD4350-AAIx-1110	Four slot mini-PCI motherboard with two 400mW Ubiquity SuperRange 5, IEEE 802.11a, 5.8GHz back-haul radios, one 400mW Ubiquity SuperRange 2, IEEE 802.11b/g 2.4GHz service radios with basic software features
MD4325-GGxx-1100	Four slot mini-PCI motherboard with two 400mW Ubiquity SuperRange 2, IEEE 802.11b/g, 2.4GHz back-haul/service radios, one 64mW 2.4GHz scanning radio with mobility software features

Table 1. Mesh Dynamics Access Point Configurations, COASTS 2006

The IEEE 802.11 equipment will be employed in the following areas:

i. Seamless network connectivity across the Mae Ngat Dam consisting of four ground based nodes and three balloon nodes laid out in an arc stretching approximately 1.2 miles. See Figures 4 and 5 below.

ii. Aboard UAV platforms enabling video and flight control and aloft in balloons to further extend the range of the network in terms of client and back-haul connections.

[16] Francis Acosta. " Why Meshdynamics Structured MeshTM is Different." Mesh Dynamics. Mesh Dynamics. 18 Sep 2006 <http://www.meshdynamics.com/WhyStructuredMesh.html>.

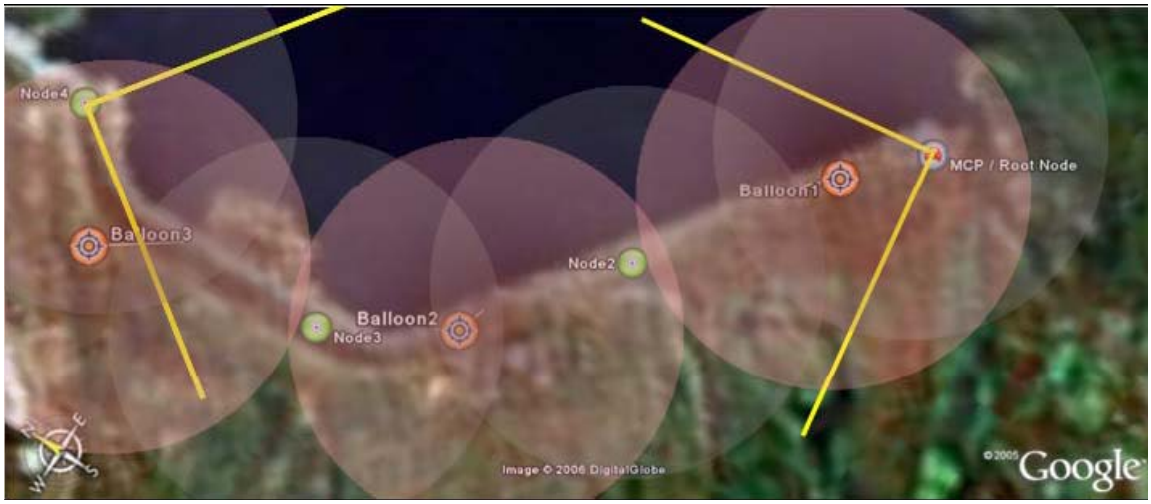

Figure 4. COASTS 2006 802.11 Network Topology
Mae Ngat Dam, Chiang Mai, Thailand (From COASTS 2006 CONOPS)

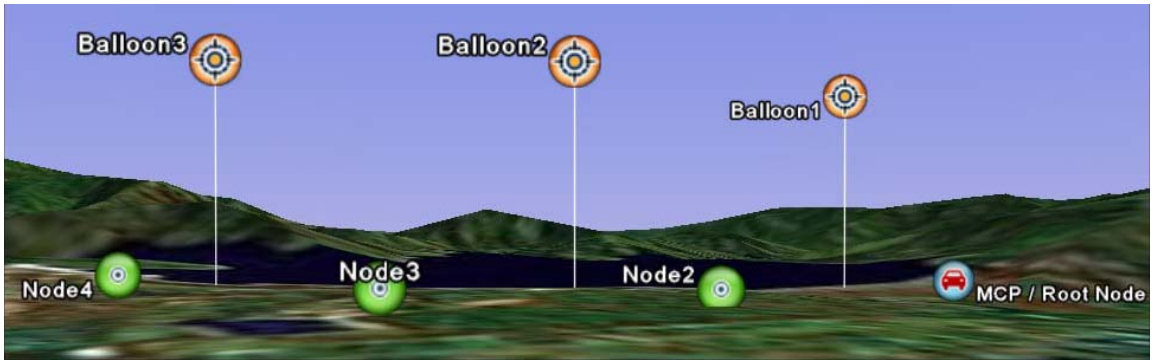

Figure 5. Side View of COASTS 2006 802.11 Topology (From COASTS 2006 CONOPS)

Several different node configurations (defined here as all equipment needed to establish connectivity) will be used to form the 802.11 seamless structured mesh network across the Mae Ngat Dam. These are defined by location below (see Figure 4 and 5 for detailed location).

- Configuration one: TOC Node (referred to as the 'root' node) (see Table 2)
- Configuration two: Lists one set which is used on Nodes 2 and 3 (total of 2 sets, one set at each node) (see Table 3)
- Configuration three: Node 4 (see Table 4)
- Configuration four: Lists one set which is used on Balloon Nodes 1, 2, and 3 (total of 3 sets to cover these three nodes) (see Table 5)

Configuration One: Root		
Equipment	**Quantity**	**Remarks**
MD43[2/5]0-AGIx-1110	1	Requires Power over Ethernet (PoE)
Mounting bracket	1	Node mount with u-bolts and screws
13dBi MP 120°/90° Single Sector (2.4/5 GHz) Antenna	2	Operating at 5.8GHz for ground based backhaul and 2.4GHz for aerial backhaul/service
MP – Omni 5dBi5 antenna	1	2.4GHz service antenna
24" RF cable	4	N series male to N series male connectors
Cat-5 cable	1	50 feet with RJ45s at each end
Tripod	1	Capable of holding a 12' x 1 ½" mast
Mast	1	12' x 1 ½" steel pipe
Cross member	1	1" x 1" x 3' angle iron to mount antennas to
HA2401gx 2.4GHz RF amplifier	1	Requires AC Power
RF amplifier power cable	1	
PoE adaptor	1	Requires AC Power
PoE adaptor power cable	1	

Table 2. Configuration One

Configuration Two: Nodes 2 and 3		
Equipment	**Quantity**	**Remarks**
MD4350-AAIx-1110	1	Requires battery power (UBI2590)
Mounting bracket	1	Node mount with u-bolts and screws
MP – Omni 5dBi5 antenna	1	2.4GHz service antenna
24" RF cable	1	N series male to N series male connectors
HG5812U-Pro 12dBi omni	2	5.xGHz backhaul antenna
N series male to N series male adapter	2	Used to connect HG5812U-Pro omni antenna
UB2590 Lithium-ion battery	1	Node power
Battery cable	1	Connection to node
Battery charger	1	For UBI2590 battery, requires AC power
Tripod	1	Capable of holding a 12' x 1 ½" mast
Mast	1	12' x 1 ½" steel pipe
Cross member	1	1" x 1" x 3' angle iron antenna mount

Table 3. Configuration Two

Configuration Three		
Equipment	**Quantity**	**Remarks**
MD4350-AAIx-1110	1	Requires battery power (UBI2590)
Mounting bracket	1	Node mount with u-bolts and screws
13dBi MP 120°/90° Single Sector (2.4/5 GHz) Antenna	1	Operating at 5.xGHz for backhaul (two upstream links)
MP – Omni 5dBi5 antenna	1	2.4GHz service antenna
24" RF cable	3	N series male to N series male connectors
Tripod	1	Capable of holding a 12' x 1 ½" mast
Mast	1	12' x 1 ½" steel pipe
Cross member	1	1" x 1" x 3' angle iron to mount antennae to
Battery cable	1	Connection from battery to node
Battery charger	1	For UBI2590 battery, requires AC power
HA2401gx 2.4GHz RF amplifier	1	Requires battery power
11.1v Lithium-poly battery	1	RF amplifier power
RF Amplifier battery cable	1	Connection from battery to amplifier
Lithium-poly charger	1	Charger for amplifier battery

Table 4. Configuration Three

Configuration Four: Balloons		
Equipment	**Quantity**	**Remarks**
MD4325-IIxx-0000	1	Requires battery power (UBI2590)
MP – Omni 5dBi5 antenna	2	2.4GHz backhaul and service
Battery cable	1	Connection to node
Battery charger	1	For UBI2590 battery
24" RF cable	2	N series male to N series male connectors
Angle aluminum brackets	2	Custom designed (see 'Graphic c.' and 'Graphic e.')
Balloon gear		See Balloon node specifications
1" x 5' sling	1	Used to secure the node inline with the balloon tether
Stainless Steel Swivel	2	Place inline with tether below and above payload
Carabineer	2	Secure sling to balloon and tether
Nylon cord	1	6' section for tying on the battery to the payload
Plastic cable ties	4	Secure brackets to sling
Axis 213 camera	1	For video surveillance if desired
11.1v Lithium-poly battery	1	Axis 213 camera power
Axis 213 camera power cable	1	Connecting battery to camera

Table 5. Configuration Four

2. 802.16

The IEEE 802.16 equipment chosen for COASTS 2006 is the Redline Communication AN-50e high speed wireless Ethernet bridge configured either for point-to-point (PTP) operation or for point-to-multipoint (PMP) operation. These devices will allow for both back-haul and access functions. The dominant reason for using Redline Communications is their proven performance during COASTS 2005 exercises. The Redline Ethernet bridges are highly configurable allowing varying radio powers, operating frequencies, in the IEEE 802.16e standards, and software configurations to suit specific applications.

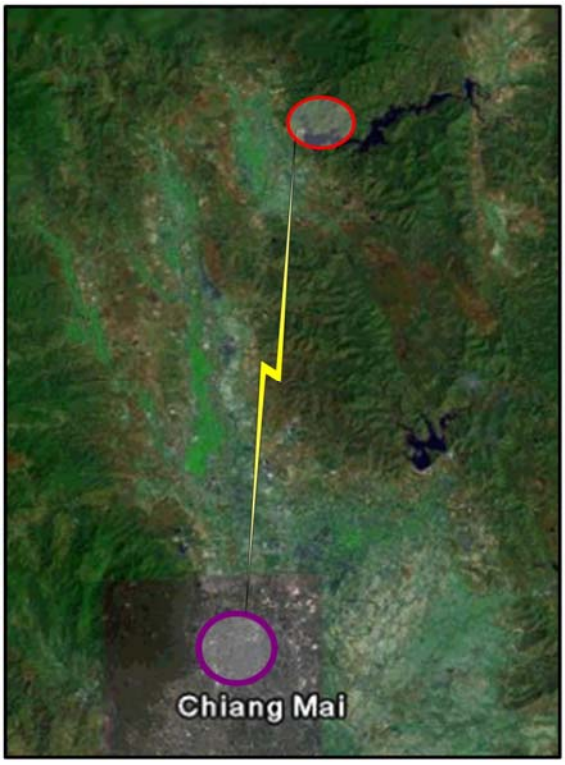

Figure 6. COASTS 2006 802.16 3-hop Back-haul Topology (From COASTS 2006 CONOPS)

3. UAV's

There is a variety of UAV equipment being operates as part of the COASTS 2006 field experimentation process. The first is the RotoMotion Vertical Take-Off and Landing (VTOL) UAV. This unit has an electric engine and a payload of up to 18 lbs. This UAV is capable of fully autonomous flight with a safety operator to perform takeoff

and landing and to engage and disengage the autonomous flight control system (AFCS). The AFCS utilizes an advanced stable-hover control system that allows for high quality video collection.

Figure 7. RotoMotion VTOL UAV (From COASTS 2006 CONOPS)

Next is the CyberDefense CYBERBUG. This parasail design has an electric engine and a payload of up to 2.5 lbs. This UAV is also capable of fully autonomous flight with a range of 14 miles using GPS. The CYBERBUG was equipped with a day/night camera capable of broadcasting live video from a distance of up to three miles.

Figure 8. CyberDefense CYBERBUG (From COASTS 2006 CONOPS)

Finally, is a COTS RC helicopter. This unit was chosen as a less expensive option to extend the wireless network as an airborne relay. It has an electric engine and a payload of up to seven lbs. This UAV is currently airline transportable as a carryon item.

The range is limited to line of sight, usually less than one third of a mile. The helicopter was also used to gather live video data using a small wireless camera.

Figure 9. COTS RC Electric Helicopter (From COASTS 2006 CONOPS)

4. Balloons

The COASTS project uses a balloon payload for two reasons. First, it can extend the mesh network and create a greater coverage area by carrying wireless access points. Second, it can carry a camera with full pan-tilt-zoom capability onboard which increases the field of view, allowing personnel to visually track any incident that may occur. Positioning the camera on the balloon provides a higher position which in turn provides a greater area of coverage for visual target acquisition

Three Blimp Works 3M Balloons provided an aerial platform for the network. Each balloon can carry a payload of 28 lbs.

Figure 10. Blimp Works Balloon (From COASTS 2006 CONOPS)

5. Remote Client

The final piece in testing the mesh network is having an individual client associate with the mesh. This enables connectivity from the network center through the mesh and ultimately terminating with the client. The hardware configurations used were:

- Dell D510 Laptop
- Proxim Orinoco Gold b/g Wireless Card
- 3dBi Rubber Bullet Multi-polar antenna

Figure 11. Remote Client (From COASTS 2006 CONOPS)

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III. DATA COLLECTION

A. FIELD EXPERIMENTS

1. COASTS' Point Sur Testing

The purpose of the Point Sur Testing was to evaluate all functional aspects of the COASTS networking project in an operational (field) environment. It was essential to deploy and integrate the equipment out of the laboratory environment to ensure that it would be robust enough for the overseas portion of the program, specifically the Thailand Field Experiment. Because there were DoD budget shortfalls early in the new fiscal year, only a few components of each part of the greater network were available for testing.[17]

a. Components

The components used for the Point Sur field experiment were addressed in Chapter 2, part C. The exception is that there were no UAV's used during this field experiment as Point Sur does not have any unrestricted airspace as required by the Federal Aviation Authority for all UAV operations.

b. Capabilities

The demonstrated capabilities of the Point Sur field experiment are organized into two categories. First, to provide mission-critical communications and second, ensure that the components used are available commercially, off the shelf (COTS). For this field experiment COASTS was able to use the Naval Postgraduate School's NEMESIS mobile command center (converted recreational vehicle) and back-haul satellite link to the World Wide Web from the 802.11 structured mesh network. In essence a small version of the final proposed network for the Thailand Field Experiment was successfully created in a remote operating area.

c. Coverage

The coverage area for the Point Sur field experiment for the 802.11 network was an area roughly three square miles. The area of coverage was centered on and around the U.S. Navy SOSUS station located at Point Sur, California.

[17] COASTS Point Sur Field Experiment After Action Report, December 2005.

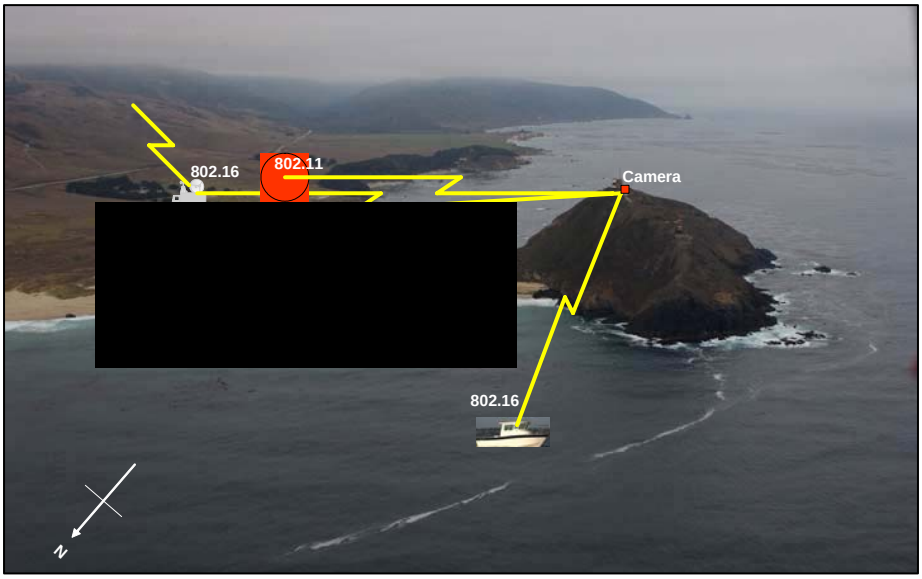

Figure 12. Pt. Sur Operation Area (From COASTS 2005 Pt Sur CONOPS)

d. Cost

The costs for the Thailand field experiment need to be broken into many different subcategories. They are listed below in Figure 8. There were no additional transportation or lodging costs incurred with this particular field experiment.

Equipment	Cost
802.11 Wireless Access Points	$8,000
802.11 Antennas / Wireless Access Cards	$2,000
Balloons / Winches / Helium	$4,000
Power (Batteries / Generators)	$1,000
NEMESIS Operating Costs	$1,000
3 Contractors	$17,000
2 Faculty Members	$10,000
Total	$43,000

Table 6. Cost for Point Sur Experiment

2. COASTS' Thailand Testing

The underlying scenario used for the COASTS 2006 field experiment was conceived to test the implementation of commercial, off-the-shelf (COTS) equipment and procedures to demonstrate test plans that: (1) potentially reduce or mitigate drug

trafficking across the Thai-Burma border, (2) provide actionable information (real-time) to local, regional, and strategic level decision-makers, and (3) shorten the sensor-to-shooter cycle.[18]

a. Components

The components used for the Thailand field experiment were addressed in Chapter 2, part C. Additional components were provided by the Thailand military and government. An AU-23 Peacemaker aircraft was used as an airborne video collection platform. Data was sent, via the WiMax back-haul, to the Inter-agency Intelligence and Fusion Center (IIFC), in Northern Thailand. This data center acted as a Command and Control (C2) Center for this experiment, but could easily be replaced by any facility needing data from a HA/DR site such a hospital or refugee camp.

b. Capabilities

The demonstrated capabilities of the Thailand field experiment are organized into numerous categories. First, to provide mission-critical communications. Second, ensure that the components used are available commercially, off the shelf (COTS). Third, demonstrate the ability for inter-operability between foreign military partners. Fourth, demonstrate the ability to operate and test in a multitude of adverse weather and terrain conditions. Finally, demonstrate the ability to address and overcome connectivity issues (bandwidth and technological limitations) with foreign C2 assets.

c. Coverage

The coverage area for the Thailand field experiment for the 802.11 network was an area roughly twelve kilometers square. The area of coverage arced around the Mae Ngat Dam, in Chiang Mai, Thailand.

[18] COASTS Thailand Field Experiment After Action Report, July 2006.

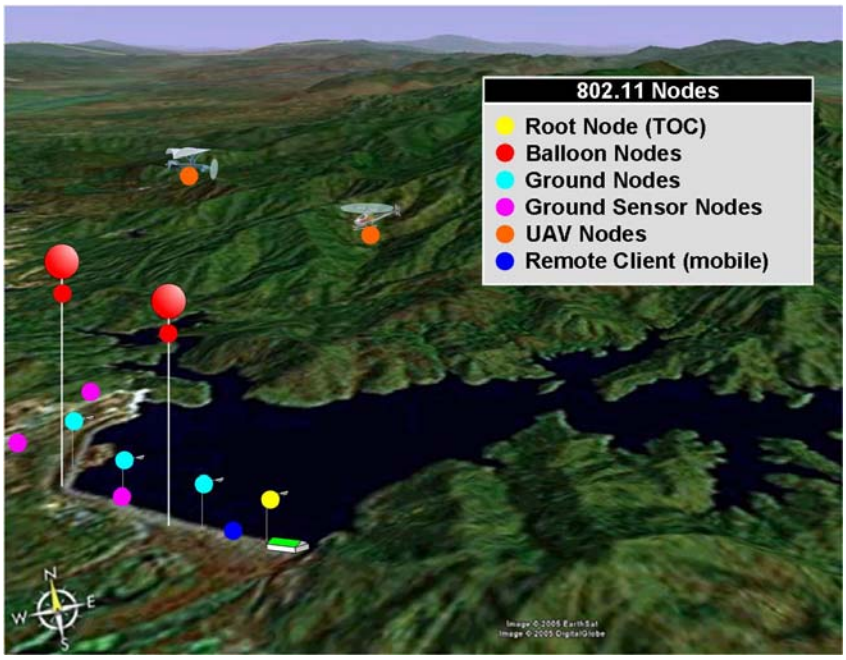

Figure 13. 802.11 Network Nodes at Mae Ngat Dam (From COASTS 2006 CONOPS)

d. Cost

The costs for the Thailand field experiment need to be broken into many different subcategories. They are listed below in Figure 13. In addition to the costs in Figure 13, there was an additional cost of $74,000 for transportation and lodging for NPS students that was incurred during the Thailand field experiment.

Equipment	Cost
802.11 Wireless Access Points	$40,000
802.11 Antennas / Wireless Access Cards	$10,000
Tactical Operations Center	$35,000
Balloons / Winches / Helium	$20,000
Power (Batteries / Generators)	$6,000
UAV's	$80,000
3 Contractors	$33,000
2 Faculty Members	$10,000
Total	$234,000

Table 7. Cost for Thailand Field Experiment

3. PacketHop's C2 Solution for GGSN (Comparable Application)

In order to add variety of field testing external of COASTS projects, additional data was collected from a homeland security field experiment simulating a terrorist attack

at the Golden Gate Bridge. Under the leadership of the California Governor's Office of Emergency Services (CGOES), the exercise was driven by the Golden Gate Safety Network (GGSN), a San Francisco-based coalition made up of federal, state and local public agencies.

a. Background

After 9/11, GGSN was in need of a multi-agency, interoperable communications system for the following requirements: [19]

- Fire, police and emergency medical personnel from Marin County and San Francisco could use interoperable broadband communications to resolve prospective terrorist threats on the Golden Gate Bridge.
- Search and rescue workers could share wireless video and images of lost teens while searching isolated areas of San Francisco's National Golden Gate Recreational Parks.
- The Incident Commander could effectively coordinate first responders on land, sea and air (after a 7.5 magnitude earthquake at Fisherman's Wharf) and do it during the critical period when the pre-existing communication infrastructure is temporarily or permanently unavailable.

To acquire such a system, GGSN requested for an IT solution from PacketHop, a Silicon Valley-based company. They were impressed with PacketHop's mobile mesh networking software that provides and wanted the advantages of having a survivable, interoperable broadband data communications system that could be setup anywhere, anytime and with any device.[20]

b. Field Experiment

GGSN formally collaborated with PacketHop to develop a commercially viable and cost-effective solution for enabling multimedia situational awareness and C2 communications. In February 2004, more than a year later, GGSN conducted a long-awaited homeland security field experiment to test the ability of multiple agencies to communicate, coordinate and respond using PacketHop's technology for the purpose of protecting the Bay Area and Golden Gate Bridge against threats.

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[19] David Thompson, "Mobile Mesh Networking: Bridge to the Future of Broadband Wireless," *Private Wireless*, Vol. 12, June/July 2004.

[20] Elena Malykhina, "An Instant and Mobile Wireless Mesh Network," *NewsFactor Network*, 29 AUG 2005

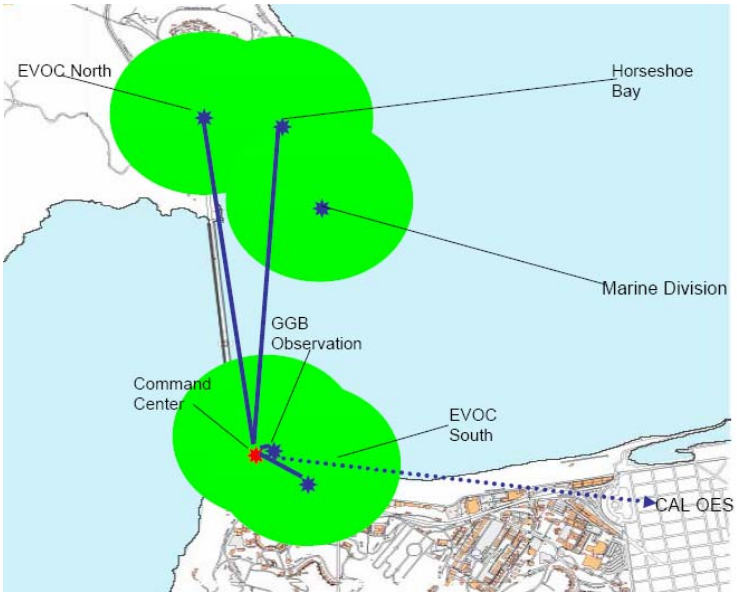

Figure 14. GGSN Area of Operations for February 2004 Experiment (From: Packethop)

The highlight of the three-hour exercise was the demonstration of the broadband mesh connectivity enabling multi-jurisdictional first responders to share and view broadband data applications, such as resource tracking on base maps, multicast video, secure multimedia messaging and white boarding, among others.[21] The first responders ranged from federal, military, police, firefighting and other agencies. PacketHop's Vice-President, David Thompson, claimed this was the first time all of these agencies were able to share mission-critical information on a real-time basis.[22]

c. Components

The complete PacketHop network system, as used during the field experiment, consisted of the following components:

- Network controller- a secure high-performance appliance that interconnects multiple mesh networks.
- Network management system- real-time control for both distributed and centralized operations.
- Network client software- installed on each wireless device.
- Modular applications- tuned for mobile mesh.

[21] "Urban Meshed Warrior," Daily Wireless, 25 FEB 2004, www.dailywireless.org/modules.php?name=News&file=article&sid=2130&src=rss10

[22] David Thompson, "Mobile Mesh Networking: Bridge to the Future of Broadband Wireless," *Private Wireless*, Vol. 12, June/July 2004.

- Situational awareness applications- PacketHop developed these set of applications, specifically for GGSN and homeland security, to bolster C2 functionality and operate in a peer-to-peer, server-less environment over any IP network and any IP device.

According to Terry Krout, Marin County Sheriff for OES, "The situational awareness applications enable everyone – whether at command center or a cop rolling on to the scene – to see the incident real-time, and then, best evaluate and leverage assets in the field."[23] This was how the first responders were able to view and share broadband data applications, such as resource tracking on base maps, multicast video, secure multimedia messaging and white boarding.

A total of 35 nodes, including a mobile van, marine units and fixed sites, were connected across diverse devices, difficult terrain and disjointed networks. Additionally, CGOES commanded the operation remotely by connecting a virtual private network (VPN) to the system. Every node was equipped with GPS capabilities for the purpose of transferring positional data. Furthermore, the network system was used to transfer video, including multiple camera angles of the same scene viewed by different nodes. Since PacketHop's technology does not require a central server, responders communicated via a peer-to-peer messaging system.

As a commercially viable solution, the PacketHop software can be easily loaded onto virtually any standard IP radio (802.11) equipped device, such as laptops, tablets and PDAs. Response agencies were outfitted with these ruggedized COTS devices. Two dozen Windows-based laptops, tablets and PDAs were supplied by partners 3eTI, Itronix, Intermec, Panasonic, Proxim, Symbol, TDS and Xybernaut.[24]

d. Capabilities

The demonstrated capabilities of the showcased solution are organized into three categories:[25]

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[23] David Thompson, "Mobile Mesh Networking: Bridge to the Future of Broadband Wireless," *Private Wireless*, Vol. 12, June/July 2004.

[24] "Urban Meshed Warrior." Dailywireless.org. 25 FEB 2004. Dailywireless.org. 18 Sep 2006 <http://www.dailywireless.org/modules.php?name=News&file=article&sid=2130&src=rss10>.

[25] Michele Spring, Thornton, Laurie. "PacketHop Deploys First Multi-Agency, Mission-Critical, Mobile Broadband Communications Network For Homeland Security." Mayfield Fund - PacketHop. 25 FEB 2004. Mayfield Fund. 18 Sep 2006 <http://www.mayfield.com/newsarticles/packethop022504.htm>.

1. **Survivable, mission-critical communications**

- Instant provisioning of survivable network
- No dependence on fixed infrastructure
- Network extension to uncovered areas
- Data delivery and security assurance on any IP network

2. **Real-time, interoperable broadband communications**

- Roaming and mobility across all networks (fixed or infrastructure-less)
- Seamless integration with all networks (fixed-to-mobile or mobile-to-mobile)
- Mobile broadband in the field with real-time, secure situational awareness

3. **Cost-effective, commercially viable solution**

- Compatible with commercial off-the-shelf (COTS) equipment
- Operates with existing devices (laptops, tablets, PDAs)
- Uses standards-based solutions for software and hardware
- Leverages Wi-Fi/802.11 and multi-mode broadband radios

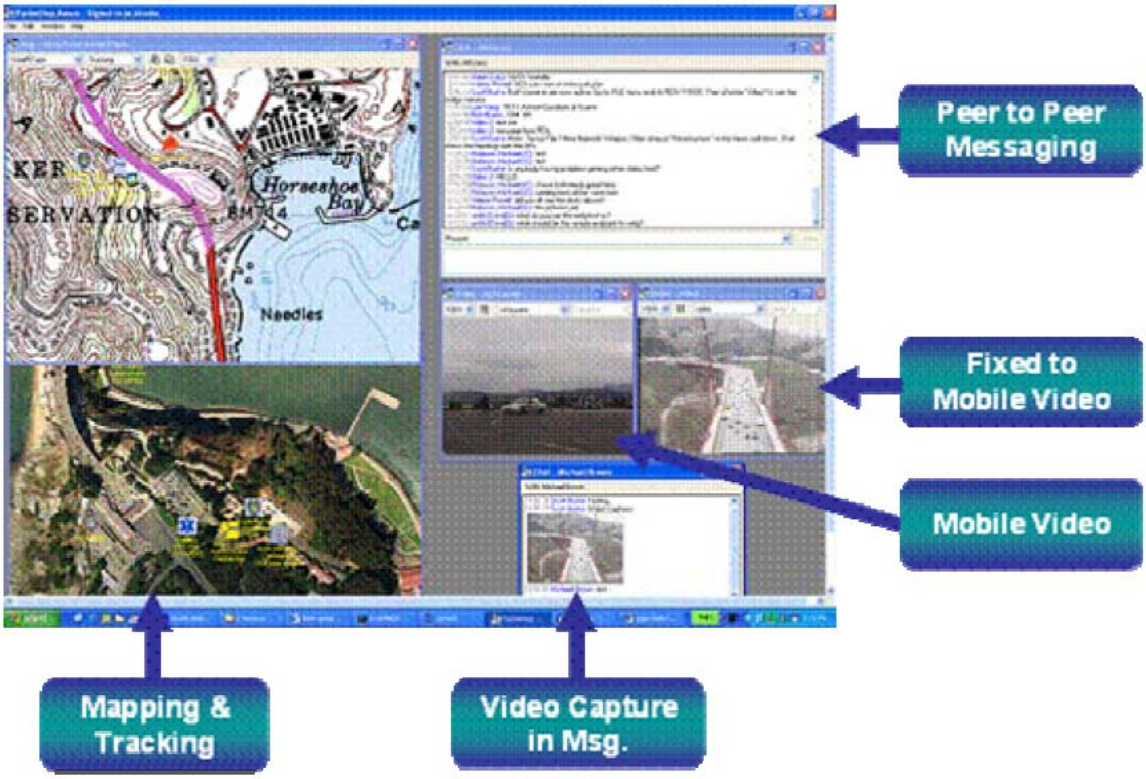

Figure 15. Screen Capture showing Packet Hop Technologies (From: Packethop)

Basically, PacketHop transformed every device involved with the exercise into a proactive router that tracked other devices in the dynamic and ever-changing wireless mesh. As a result, every field device was more than capable of communicating with each other, along with any traditional fixed IP infrastructure (802.11 access points) that may have been available. The significance of this was that a mobile, high-secure, interoperable and survivable broadband communication system was formed instantaneously. In addition, data transmissions were optimized because each device made efficient use of all the network resources available to it.[26]

The PacketHop software authenticates all the users, allowing them to use instant messaging and video conferencing. It also displays the location of the responders if they are GPS equipped. As required by the HA/DR operations, users are added to or removed from the network on the fly. The one capability the PacketHop solution did not support for the field exercise was voice.[27] Again, the experiment was performed in 2004 and PacketHop anticipates incorporating voice capabilities to their software in the near future.

e. Coverage

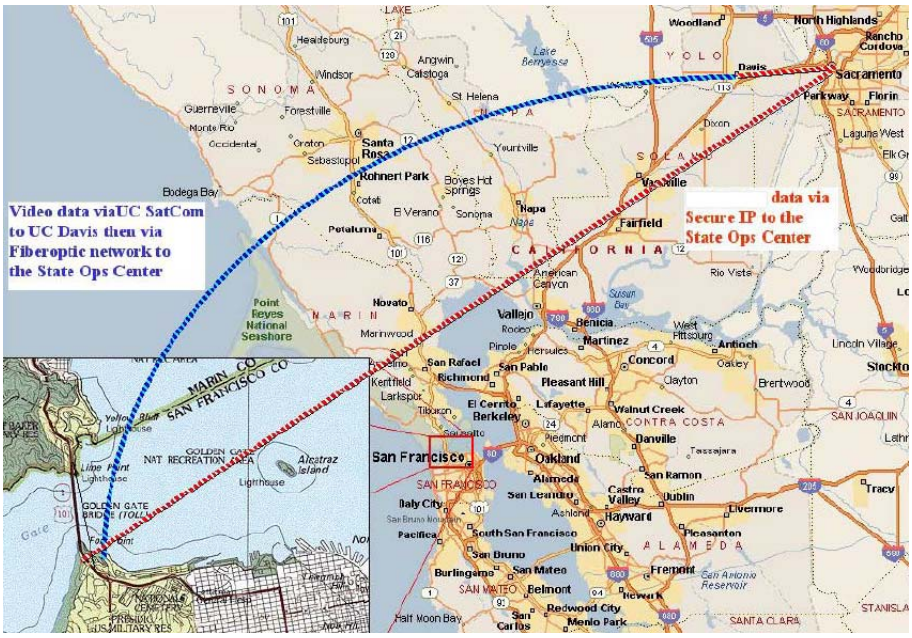

Figure 16. Coverage Area for the GGSN 2004 Field Experiment (From: Packethop)

[26] David Thompson, "Mobile Mesh Networking: Bridge to the Future of Broadband Wireless," *Private Wireless*, Vol. 12, June/July 2004.

[27] Andrew Kantor, "In the communication age, connection is everything," *USA Today*, 08 DEC 2005.

With communication vehicles and devices (high-gain antennas) in place, PacketHop's network system spanned approximately 150 miles over land and sea; extending from the Presidio north to Marin County and including nodes on Coast Guard and San Francisco Police Department ships in the bay.[28] During the field exercise, the system connected first responders that were positioned around the Golden Gate National Recreational Area to a local incident command center and the CGOES operations center in Sacramento.[29]

f. Cost

> Mesh networking in various applications is becoming a low-cost alternative for municipalities. Cities and towns should evaluate mesh technologies to enhance data communications and improve public safety interoperability. Behind such deployments are productivity gains, ease of deployment, and the ability to deliver first responder interoperability at a fraction of the cost of a land mobile radio system.
>
> - Jeff Vining, vice president of Gartner Research, in a Gartner market research report titled "Mesh Networking Improves First Responder's Efficiency."[30]

A detailed cost breakdown of PacketHop's solution, as used during the 2004 field experiment, was not disclosed by the company or GGSN. For marketing and commercial-modification purposes, the company is not advertising the cost of the solution. Just recently in August 2006, PacketHop introduced the new software as the "Communication System for Public Safety" and advertised that it delivers instant, mobile broadband communications for law enforcement agencies and mobile workgroups in the enterprise. The following product specifications and requirements are taken directly from the company's official website:

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[28] Griffith, Eric. "Meshing with Homeland." Wi-Fi Planet. 26 FEB 2004. Wi-Fi Planet. 18 Sep 2006 <http://www.wi-fiplanet.com/news/article.php/3318551>.

[29] "Urban Meshed Warrior." Dailywireless.org. 25 FEB 2004. Dailywireless.org. 18 Sep 2006 <http://www.dailywireless.org/modules.php?name=News&file=article&sid=2130&src=rss10>.

[30] "Archived news extracts about GPS and Wireless Technologies 2005." GPS-practice-and-fun. 11 JUL 2005. GPS/Wireless. 18 Sep 2006 <http://www.gps-practice-and-fun.com/archived-gps-wireless-news-2005.html>.

(1) Product Specification.

Network:

- Support for standard IEEE 802.11a/b/g WiFi and 4.9 GHz spectrum
- Multicast - send data such as video or Instant Message to multiple people simultaneously
- Multihopping: Passes data through computers to reach other users in the mesh, even if they are out of range of the originating computer. No practical limit on the number of hops - latency will increase with multiple hops but can be decreased with increased CPU
- Optimized for transmission over faster WiFi and 4.9 GHz local connections as well as slower cellular or satellite back-haul networks. Adapts to network and network conditions
    - Optimize between multicast and unicast to conserve bandwidth
- Security
    - WPA2 security with AES encryption at the wireless layer
    - SSL VPN with AES encryption provides secure tunneling on top of the wireless layer
- Performance Criteria
- Range: up to 1 km line of sight in the 4.9 GHz band
    - Throughput: Traffic shaping optimizes throughput for high and low bandwidth network connections

Applications:

- Video
    - View up to 4 video streams over high bandwidth networks
    - View 1 video stream over cellular networks
    - Video streams only sent on viewer request to maximize bandwidth. Otherwise, video thumbnails are sent
- Mapping
    - Integrate with any standard maps
    - Use maps with or without GPS for location tracking
- White boarding
    - White board on video screens, maps or blank screens

- Instant Messaging (IM)
    - Insert standard public safety shortcuts
    - Message one or multiple people
    - Configure groups on-the-fly or preset groups
    - Send files such as pictures or reports

Systems Management Console:

- Web-based administration
- Acts as a VPN gateway and router and provides communication between multiple submeshes
- Provides provisioning of client devices
- Supports up to 500 users simultaneously

(2) System Requirements

Client System Requirements:

- Windows XP Service Pack 2
- Windows XP Tablet PC Edition 2005
- Microsoft .NET Framework Version 1.1
- Processor: 1 GHz Pentium 4 or Pentium M or later with 512 K L2 cache
- RAM: 256 MB minimum; 512 MB recommended
- Hard Drive: 20 GB, minim 1 GB free
- PacketHop specified network interface card (NIC)
- B PacketHop recommended antenna and cables

Server System Requirements:

- The Systems Management Console (SMC) is delivered from PacketHop preinstalled on a standard server and requires only a network connection

Optional accessories:

- Video cameras
- GPS receivers [31]

Cost for the software might be the biggest concern for most public safety agencies, at least for those without any Homeland Security funding. PacketHop will charge a fee based on the number of users with annual maintenance support contracts. Company representatives would not definitively state the price, but estimated it at around $2,000 per end-user device, while the management console with Gateway software will cost around $25,000.[32]

"It might be more than some laptops," says David Thompson, PacketHop's vice president of marketing, "but this is a brand new, breakthrough technology." Thompson compared it to the price of installing a permanent infrastructure for mesh networking, citing a frequently-used number in some circles of $160,000 per square mile to install permanent mesh equipment. He further states that even a permanent mesh infrastructure will still have holes and may not be capable of penetrating through buildings; as Thompson implied PacketHop's network is capable of doing, assuming it has enough nodes. PacketHop is aware of the $10.9B allocated by the federal government for helping first responders improve equipment. This is the target audience that the company is relying on for profitable returns.[33]

31 "Mobile-Mesh Communication Systems." PacketHop Communication without limitation. PacketHop. 18 Sep 2006 <http://www.packethop.com/public_safety>.

32 Roland Piquepaille. "An instant and mobile wireless mesh network." Roland Piquepaille's Technology Trends . 24 JUN 2006. primidi.com. 18 Sep 2006 <http://www.primidi.com/2005/08/30.html>.

33 Eric Griffith. "Instant Connection for First Responders." Wi-Fi Planet. 22 AUG 2005. Wi-Fi Planet. 18 Sep 2006 <http://www.wi-fiplanet.com/news/article.php/3529111>.

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IV. FINANCIAL OPPORTUNITIES

A. MARKET COMPARABLE APPROACH

1. Overview

The DoD is adopting commercial business practices in an effort to make better business decisions, increase operational efficiencies and improve cost control. The Market Comparable Approach is a means of "determining a value indication of a business, business ownership interest, security or intangible asset by using one or more methods that compare the subject to similar businesses, business ownership interests, securities or intangible assets that have been sold."[34] In simpler terms, this methodology looks at what the market would pay for the asset. Other activities may refer to this practice as the Guideline Method because it directs appraisers to use a similar public company as a guideline for valuing a private company.[35] One of the focuses of this research was identifying public companies that utilize mobile network communications for operations in rural environments and using these businesses as a guideline for valuing the DoD services in HA/DR situations.

The Market Comparable Approach is a seasoned business practice in the real estate profession but it is a new practice in the DoD. In determining market value, the real estate appraiser seeks data on sales of comparable properties while the business appraiser seeks data on transactions of comparable businesses. By investing in commercial HFN technology, the DoD is taking the perspective of the business appraiser. The market for businesses has a tendency to change more rapidly than the market for real estate due to tangible and intangible assets. These assets each have their own price instability and risks of ownership. A general rule in determining the guideline company selection is that analysts should keep in mind the underlying investment risk and expected rate of return characteristics of the public company in comparison to the subject company/organization (DoD activity in this case).[36]

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[34] International Glossary of Business Valuation Terms, June 2001.

[35] Neal Fisher, "Valuation: Theory vs Practice." Miller, Cooper & Co., LTD. 23 MAY 2006 <www.millercooper.com/lib_valuation5.htm>.

[36] Shannon P. Pratt, Robert F. Reilly and Robert P. Schweichs, "Valuing a Business", 4th Edition, McGraw-Hill Publishing, 2000, pp 45-47, 232.

Typically, it is difficult to find a set of good guideline companies to match the uniqueness of the DoD mission-critical requirements (i.e.- support readiness and war-fighting/MOOTW capabilities) and funding processes (appropriations, reimbursables and revolving funds). DoD business practices are also constrained by government regulations and military specifications. For the most part, the DoD is effective in achieving its missions, but it lacks the efficiency needed for competitive business. Adopting private-sector methodology, such as the Market Comparable Approach, can help improve the efficiency of DoD's business practices. In the commercial market, businesses are governed by the laws of supply and demand and management is focused on revenue generated profitability, return on investments (ROI) and cost control.[37] The DoD is a non-profit organization, but it is still concerned in making smart decisions regarding ROI and cost controls. Comparing military network capabilities for crisis control with emergency response services of private enterprises can help improve cost controls through comparison of estimates versus actual costs and extract substantial ROI in the long term by examining the variables that significantly affect the benefit over cost ratio.

2. Guideline (Market Comparable) Business Selections

> The use of comparable publicly held corporations as a guide to valuation, as a practical matter, may be the most important and appropriate technique for valuing a privately held operating business. Obviously finding a business exactly the same as the enterprise to be valued is an impossibility. The standard sought is usually one of reasonable and justifiable similarity. This degree of likeness is attainable in most cases.[38]

Determining a market comparable for this research required the narrowing down of several organizations and businesses that have the need to establish C2 capabilities in isolated or undeveloped areas. The following businesses that were first eliminated from our research selection were actually descent market comparables, considering they all expected to operate in rural environments:

- Non-hazardous field research
- Mobile educational/training institutes
- New development or construction companies

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[37] "The Free Market Approach." OSD Comptroller iCenter. DoD Office of the Secretary of Defense. 18 Sep 2006 <http://www.dod.mil/comptroller/icenter/dwcf/freemarket.htm>.

[38] Frank M. Burke, Jr., *Valuation and Valuation Planning for Closely Held Business*, 1981, pg 49.

- Outdoor concert event or fairground coordinators
- Traveling circuses or carnivals
- Farm, winery or plantation businesses

These possible market comparables were missing the key element of urgency. This urgency is driven by the state of emergency caused by natural or man-made disasters, requiring the organization to respond and possibly enter "harm's way." Experts of the market comparable approach would still recommend to use this group of businesses to shed some light on market value concerns, but focus on one or two directly comparable to the DoD than the rest. Data can be tabulated for the whole group but value more weight on the data collected from the guideline businesses considered most comparable.[39] Fortunately for this research, the industry for emergency network capabilities for crisis situations has recently grown due to the obvious need from recent natural disasters. The following professional businesses are market comparables that better match the requirements of our study:

- News reporting teams or field journalists
- Hazardous field research (i.e.- Tornado "Chasers")
- Surveillance teams
- Ambulance service providers
- Firefighter/Police/Emergency response teams

These are ideal organizations that would benefit from mobile network communication systems. From this category, the search for a guideline business selection began.

3. First Selection

There are several types of ambulance service providers, such as volunteer, municipal, municipal third, combined and hospital-based services. In the U.S., ambulance services may be provided by a private company that may either be a non-profit charity or profit-driven business.[40] Private ambulance providers serve as a community's safety net for those regularly occurring 9-1-1 system calls for first response, patient care and transport. There are numerous commercial ambulance service providers

[39] Shannon P. Pratt, Robert F. Reilly and Robert P. Schweichs, "Valuing a Business", 4th Edition, McGraw-Hill Publishing, 2000, pg 231.

[40] "Private ambulance companies." wikipedia. wikipedia. 18 Sep 2006 <http://en.wikipedia.org/wiki/Ambulance#Private_ambulance_companies>.

advertised on the world-wide web, so to narrow the selection process, only well-established and locally stationed companies were considered for this market comparable study.

Approximately 90% of the emergency medical services response and patient transport in California communities falls to private ambulance operations during a natural disaster, act of terrorism or other large scale incident.[41] This commercial industry routinely sends ambulance resources to support local public safety agencies, which include fire departments and law enforcement agencies, at mass casualty incidents such as recent wildfires, train derailments and floods.

The nation's leading provider of medical transportation is American Medical Response Inc. (AMR), a subsidiary of Emergency Medical Services Corp.[42] This well-established private company has more than 18,000 paramedics, emergency medical technicians (EMTs), nurses, doctors and other professional support staff that annually transport nearly 4 million patients nationwide in non-emergency, emergency and critical situations. AMR is headquartered in Greenwood Village, Colorado and locally operated in 36 states and the District of Columbia. Operating a fleet of approximately 4,400 vehicles, they serve more than 250 communities in both western and eastern regions.[43]

Figure 17. American Medical Response Emergency Response Team (From: AMR.net)

[41] "California's Emergency Medical Response Systems in Crisis." Medical News Today. 27 FEB 2005. Medical News Today. 18 Sep 2006 <http://www.medicalnewstoday.com/medicalnews.php?newsid=20420>.

[42] Moore, Douglas. "AMR is Awarded FEMA Contract for Disaster Response in New Orleans and South Louisiana." CNBC Money. 21 AUG 2006. CNBC. 18 Sep 2006 <http://news.moneycentral.msn.com/ticker/article.asp?Feed=BW&Date=20060821&ID=5961309&Symbol=US:EMS>.

[43] Ibid

Furthermore, AMR is consistently involved in HA/DR operations. During Hurricane Katrina, AMR provided the following services[44]:

- 9-1-1 EMS services in Gulfport, Mississippi and provided ambulance service in several other communities within the state.
- Mobilizing resources and making preparations for hurricane victims prior to the storm actually hitting the coast.
- Provided an additional 100 plus ambulances and nearly 300 paramedics, EMTs and other professionals to aid with the rescue, transportation and medical care to hurricane victims.
- Coordinating with federal, state and local officials in deploying additional unit and crews where they are most needed.
- Continuing to aid in rescue operations and provide medical care and transport to hurricane victims in the coastal areas of Mississippi, Louisiana and Alabama.
- Providing additional resources in Texas to aid in the transport of evacuees to medical facilities in Houston, San Antonio and Arlington. AMR anticipated the situation would escalate as additional evacuees arrive and patients were transported from existing disaster centers.

In a market comparable study, it makes sense to be interested in comparing the value of having commercial ambulance services that provide medical transport and care in the operational field against the value of multiple agencies utilizing an available network system as an effective means of C2 capabilities during a crisis response. In addition, researching the profits that AMR achieved from the Hurricane Katrina situation could be helpful in determining the financial value of HFNs in a business perspective. For these reasons, AMR was chosen as the first guideline business selection for the financial analysis.

4. Second Selection

The next business selection is focused on firefighters, the first responders who work closely with other emergency response agencies, particularly local and state police departments. U.S. firefighters work under the auspices of fire departments that are generally organized as local or county government subsidiaries, special-purpose district entities or not-for-profit corporations. The federal government, as well as some state

[44] Deborah Hileman. "Hurricane Katrina Fast Facts." AMR News. AMR. 18 Sep 2006 <http://www.amr.net/news/releases/Katrina.asp>.

governments, operates fire departments to protect their wild lands.[45] Nationwide, only a small number of U.S. fire departments are privatized. But in recent years, the number of private firefighters in the western region has grown significantly.[46]

Private firefighters have been helping out with wildfires throughout the west; almost 2,000 from Oregon alone. An astounding 98 out of 121 Oregon-based crews, dispatched to fires in Colorado, New Mexico, Arizona, Utah and Nevada, were contracted from private companies.[47] During busy wildfire years, the Forest Service generally turns to contract crews when a number of large fires are burning and the availability of fire crews is scarce. In such instances, the private crews are often assigned to the larger fires while the federal crews handle the initial attack of new fire outbreaks.[48]

Beginning in the 1990's, the federal government started outsourcing private crews on a larger scale in Oregon and Washington. By the turn of the century, the number of private firefighters dispatched from the Northwest surpassed government crews.[49] Grayback Forestry (GF), one of the Oregon-based private companies, provides multiple contract services which include firefighting crews, portable showers, fire engines and helicopters that assist the U.S. Forest Service and other firefighting government agencies. During summer months, they provide wildfire suppression and emergency services, providing Type 2 and Type 2 IA crews, Type 6 engines, Type 4 engines and tactical tenders. In 2003, GF provided 15 crews of 20 responders to help battle the western wildfires.[50]

For this study, GF was chosen as the second guideline business selection because of their role as first responders to wildfires and their status of being a privatized, profit-

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[45] "Firefighting Worldwide." wikipedia. wikipedia. 18 Sep 2006 <http://en.wikipedia.org/wiki/Firefighting_worldwide>.

[46] "Report shows private firefighters poorly trained." KOMO 4 News. 18 SEP 2006. Seattle Times. 18 Sep 2006 <http://ww3.komotv.com/Global/story.asp?S=4667493>.

[47] Geoffrey F. Sefal. "Private Firefighters Battle the West's Wildfires." reason.org. 30 OCT 2003. reason.org. 18 Sep 2006 <http://www.rppi.org/privatefirefighters.shtml>.

[48] Shannon Dininny, "Report finds Forest Service must strengthen oversight of contract firefighters," *San Diego Union Tribune*, 21 MAR 2006

[49] Geoffrey F Sefal,. "Private Firefighters Battle the West's Wildfires." *Reason Public Policy Institute*. 30 OCT 2003. reason.org. 18 Sep 2006 <http://www.rppi.org/privatefirefighters.shtml>.

[50] Ibid

driven business. Much can be learned from the value of their services during HA/DR operations and the financial expense at which the state or federal government pays for such emergency response services.

B. KNOWLEDGE VALUE ADDED

Knowledge Value Added (KVA) is a framework for measuring the value of corporate knowledge assets. Rooted in the knowledge economy, this framework provides several business valuation tools that can be used by companies to measure the value of knowledge embedded in company core processes, technology, and employees. The reason for KVA's growing acceptance as a valid measurement tool lies in its theoretical foundation and its ease of use for companies competing in the evolving knowledge-intensive global business environment.

KVA methodology provides a way to measure the value of knowledge assets deployed in core processes objectively. Valuation, the measurement of the value of knowledge in company core processes, technology, and employees, is accomplished through two return ratios: return on knowledge (ROK) and return on process (ROP). The numerator of the ratio represents the percentage of the revenue or sales dollar allocated to the amount of knowledge required to complete a given process successfully, in proportion to the total amount of knowledge required to generate the corporation's total outputs. The denominator of the ratio is the cost to execute the process knowledge.[51]

Return on Knowledge (ROK) can be determined in two different manners. First, you can measure the amount of knowledge, when applied to a process, produces the outputs of that process. The output may be a product, or a service. Second, you can measure the cost of acquiring the knowledge and applying it to produce the output. The major difference between this measurement and traditional methodologies is that KVA is concerned with the cost of acquiring and applying knowledge, not just with the costs associated with what is used to produce a product or service.[52]

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[51] Thomas Housel, Arthur H. Bell, *Measuring and Managing Knowledge*, McGraw-Hill Irwin, 2001.

[52] Glenn R. Cook, Jefferson D. Dyer, "Business Process Reengineering With Knowledge Value Added In Support Of The Department Of The Navy Chief Information Officer" September 2003.

By applying KVA to a process you can determine the association of knowledge to value for an entire activity. KVA produces a common unit of knowledge that serves as a surrogate for units of output in a standard way.[53]

In order to understand the concept of KVA one must first understand the assumptions that are the basis of the process. Using the below assumptions, KVA can show that knowledge can be used as substitutes for value when value is created by a process. This allows an organization to produce a standard unit of output for very dissimilar processes.

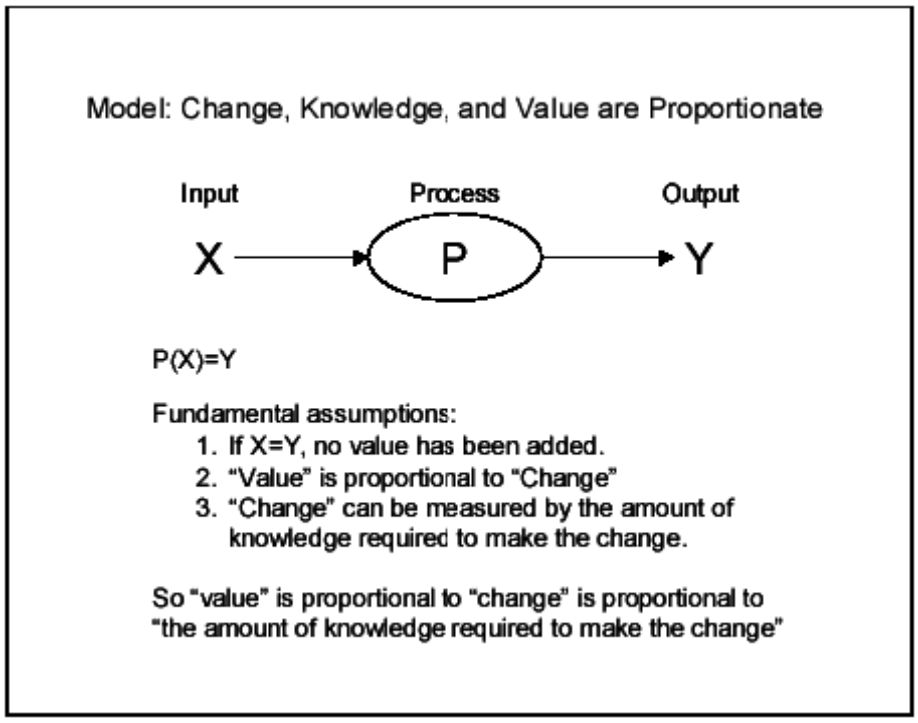

Figure 18. KVA Assumptions (From Thomas Housel)

A pillar of KVA is Learning Time. The amount of knowledge in a process can be represented as the amount of time necessary for the average person to learn how to complete the process correctly. On average, using a common individual as a reference point, learning time is proportionate to the amount of knowledge learned. Learning time can be used as a common-sense indicator of the amount of knowledge within a given

[53] Thomas Housel, Arthur H. Bell, *Measuring and Managing Knowledge*, McGraw-Hill Irwin, 2001.

process. SMEs for a given process can provide good estimates of the learning time required for a given process based on formal and informal training times, experience on the job, employee interviews, training manuals, and programs.[54] KVA makes possible the initial estimate for allocating revenue or sales dollars to the various core processes or functional areas. The goal is to establish relative orders of magnitude for the amount of knowledge embedded in core processes so that an analyst can determine which processes are more valuable or important than others.[55]

This approach may be used to estimate the amount of knowledge contained in IT. Mangers must focus on IT outputs in a core process and then use an SME to estimate the time necessary to learn how to manually generate the same output. An easier way to think of this is to ask the SME to imagine that we have just removed all of the IT and must now reproduce the outputs by teaching the average person to produce them manually. What must be determined is the learning-time estimate of how long it would take a person to learn to produce the given outputs.

The actual time it takes to execute the subprocess is a flow-based estimate of its cost. KVA calculates the cost of a process in a new way by providing a cost-per-equivalent-unit output and described as a unit of knowledge.[56]

C. FINDINGS

1. Private Ambulance Service Providers (AMR)

The information gathered for this section is aimed to help determine the value of having commercial ambulance services available on-scene of the actual disaster to provide medical transport and immediate patient care. The sources accounting for and data collected from AMR, the first guideline business selection, were dated from late-1990 to mid-2006. As discussed in Section A of this chapter, AMR is the country's leading provider of medical transportation and is locally operated in 36 states and the District of Columbia.

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[54] Thomas Housel, . "KVA." Naval Postgraduate School. Monterey, CA. 15 FEB 2006.

[55] "Knowledge Value-Added (KVA) Methodology." IEC On-Line Education. 2005. International Engineering Consortium. 18 Sep 2006 <http://www.iec.org/online/tutorials/kva/topic01.html>.

[56] Ibid.

a. Levels of Service in Crisis

As the skill requirements for various medical professions continue to increase, the differentials between the levels of care from ambulance service providers are becoming increasingly vague.[57] Skills that were once reserved for physicians are now routinely performed by paramedics and skills once reserved for paramedics, such as defibrillation, are now routinely performed by EMT-Basics. Furthermore, there is wide state-to-state, and sometimes county-to-county, variation of what types of medical care providers at different levels are allowed to provide. That said, the following are the different levels of care service:[58]

- Certified First Responder (CFR) – Usually consist of personnel in a rural setting in which ambulance transport is delayed due to distance. In these cases, responders render very basic first aid to include oxygen administration to patients until a more definitive transport unit arrives.
- Basic Life Support (BLS) – Usually consists of two EMT-Basics and provides oxygen therapy, splinting, bleeding control, defibrillation with an AED and light extrication (i.e. – removing a victim from a car, but not using the Jaws of Life).
- Intermediate Life Support (ILS) – Usually consists of an EMT-Basic and an EMT-Intermediate. EMT-Intermediates provide BLS care with the addition of IV therapy and often intubation.
- Advanced Life Support (ALS) – Usually consists of an EMT-Basic or EMT-Intermediate and an EMT-paramedic. EMT-paramedics provide BLS care and ILS care with the addition of manual defibrillation and advanced electrical therapy including transcutaneous pacing (i.e. – fitting a temporary pacemaker to the patient's chest) and synchronized cardioversion (an advanced form of defibrillation), intubation, medication administration, pleural (chest) decompression and more.
- Mobile Intensive Care Unit (MICU) – Usually consist of either an EMT and a paramedic (or multiple paramedics) and provide the full range of advanced services to include IV therapy, cardiac monitoring and drugs, pain killers, etc. In some locations, physicians may be included.
- Critical Care Units (CCU) – Usually consist of a combination of EMTs/Paramedics/Nurses/Physicians depending on the need and service. They may provide special transports for premature babies, cardiac transfers, etc.

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[57] "Ambulance." wikipedia. wikipedia. 18 Sep 2006 <http://en.wikipedia.org/wiki/Ambulance#Private_ambulance>.

[58] Ibid.

Depending on certain county-to-county variation requirements, AMR, being a well-established company, is capable of providing as high as CCU services for HA/DR events. They were involved in multi-state, long-term rescue and recovery efforts of victims at the World Trade Center during 9/11. In addition, AMR was Oklahoma City's contracted provider during the 1995 Murrah Federal Building bombing with company paramedics and EMTs first on the scene to rescue and treat victims.[59]

b. Resources and Capabilities

According to AMR's official website, the company has the following resources and capabilities and offers the following services and benefits: [60]

- Leadership – In crisis situations, AMR provides experienced leadership in the medical field. The men and women who make up AMR's leadership have an extraordinary combined depth of experience and knowledge that brings an understanding and creativeness to a HA/DR situations. Some of the team leaders began their careers as either paramedics or EMTs and worked their way up the corporate ladder, while others held executive positions in the healthcare industry.
- Personnel and Staff Support – Over 75% of AMR's 18,000 employees are in medical and support positions that work directly in patient and customer care. The remainder of the employees share in the mission of clinical and customer service by supporting the front-line teams. Their depth and resource strength are considered unmatched in the medical transportation service industry. AMR paramedics, EMTs and other professionals transport nearly 4 million patients nationwide each year.
- Nation-wide Locations – With locations across the country, AMR provides the strength of a national company with the service of locally managed community operations. Headquartered in Greenwood Village, CO, AMR serves more than 250 communities in both western and eastern regions.
    - The East region has local operations in Alabama, Connecticut, Florida, Georgia, Indiana, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Mississippi, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, South Carolina and Virginia. This region employs more than 7,000 healthcare professionals and support staff and is headquartered in New Haven, Connecticut.

[59] "The History of AMR." AMR. AMR History. 18 Sep 2006 <http://www.amr.net/company/history.asp>.

[60] "About AMR." AMR, About AMR. AMR. 18 Sep 2006 <http://www.amr.net/company/index.asp>.

- The West Region has local operations in Arkansas, California, Colorado, Hawaii, Iowa, Kansas, Missouri, Montana, Nevada, New Mexico Oklahoma, Oregon, South Dakota, Texas, Washington and Wyoming. This region employs more than 11,000 professionals, serves more than 5.8 million people each year and is headquartered in Livermore, CA.

- Partnership with Local Agencies – AMR works with private and public partners, including other ambulance service providers, hospitals, fire and police departments, to provide public safety and care. For example, police and fire professionals may be first responders to an incident with AMR partnering to provide medical care and transport the victim(s). EmCare, an AMR partner, is involved by staffing more than 4,000 emergency room physicians across the nation who standby to treat patients in crisis. Additionally, AMR dispatchers/crews remain in constant radio and phone communication with the local police/fire dispatch center.

- Technology Advanced Equipment – They include the following:

  - New Global Positioning System (GPS) systems that allow better tracking of all ambulances in the area and new Pinpoint Computer-Aided Dispatch (CAD) systems that are designed to ensure more sophisticated system tracking/reporting capabilities. These technological benefits lead to smoother transfer of patient calls, response and care.

  - State-of-the-art clinical equipment that can have a positive effect on cardiac arrest survival rates.

  - Support equipment to support basic ambulance services, 9-1-1 emergency responses skills, helicopter rescues on mountains or at sea and rescues at major sporting events (NFL, NASCAR, etc.).

These resources and capabilities were demonstrated during AMR's involvement in the Hurricane Katrina relief efforts. They set an off-site command center to manage the deployment of AMR ambulances from other operations and to coordinate response efforts with federal, state and local authorities. During the aftermath of Katrina and Hurricane Rita, AMR deployed more than 100 out of state ambulances and medical crews to coastal Mississippi, southern Louisiana and eastern Texas.[61] The private company maintained the majority of that fleet for several weeks, providing emergency medical services and patient evacuation. Of course, with most profit-driven businesses, these services came with a fee to the government and, ultimately, taxpayers.

[61] Deborah Hileman, "American Medical Response Sends Ambulances, Medics to Mississippi Coast," AMR News, 31 AUG 2005,

c. FEMA Contracts

When Katrina hit the Gulf Coast at the end of August 2005 and the regional devastation received world-wide attention, Congress quickly passed the emergency appropriations bills totaling $62.3B. The amount was allocated as follows:[62]

- $60B to the Federal Emergency Management Agency (FEMA) for recovery efforts that include aid to families, debris removal and public assistance.
- $1.9B to the DoD for evacuation, repairs and deploying personnel.
- $400M to the Army Corps of Engineers for restoring and repairing New Orleans levees and pumping stations.

According to a contract data listing from the *Taxpayers for Common Sense* website, an independent/non-partisan source, FEMA awarded AMR eight contracts in support of Hurricane Katrina totaling about $16.56M. Table 8 lists the contracted AMR divisional offices, individual contract costs, dates and contract details.[63] However, this $16.56M total of combined contracts is considered minor in comparison to what happened the following year.

After a nation-wide bid in 2006, FEMA awarded AMR, along with another company, ACADIAN, a contract to provide emergency medical transportation and para-transit evacuation services for the city of New Orleans and 12 coastal Louisiana parishes for any disaster that requires federal evacuation assistance.[64] Within 24 hours of notification, the federal government could task order these two emergency transportation providers to provide up to 488 ambulances and para-transit vehicles capable of moving nearly 5,400 special need evacuees within 72 hours. The value of this dual contract for emergency services is $265M and is effective from 14 August through 30 November 2006 (approximately 16 weeks), with optional short term extensions if necessary.[65]

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[62] Katie Ackerly. "Hurricane Katrina, Response and Recovery." GAP - Government Affairs Program. 6 JUNE 2006. AGI - American Geological Institute. 18 Sep 2006 <http://www.agiweb.org/gap/legis109/katrina.html>.

[63] "The Costs of Katrina: Rebuilding the Gulf." Taxpayers for Common Sense. Taxpayers for Common Sense. 18 Sep 2006 <www.taxpayer.net/budget/katrinaspending/tcscontractslist.pdf>.

[64] Douglas Moore, "AMR is Awarded FEMA Contract for Disaster Response in New Orleans and South Louisiana," *Business Wire*, 21 AUG 2006

[65] "Federal Agencies Collaborate To Aid Special Need Evacuations." FEMA. 18 AUG 2006. FEMA. 18 Sep 2006 <http://www.fema.gov/news/newsrelease.fema?id=29021>.

AMR's financial records are not publicly accessible, thus, this research was limited in providing an accurate dollar amount of profits the company benefited from Katrina and Rita.

City	State	K Value	Competition	Date	Contract Details
Miami	FL	$ 806,000	Not Full/Open - Other	10/1/2005	Ambulance Services
Clarkston	GA	$ 430,080	Not Full/Open - Other	9/27/2005	8 (AFS) Advance Life Support Ambulances for 30 Day Support
Clarkston	GA	$ 921,600		9/27/2005	Staffed w/ fully licensed techs/8 (AFS Advance Life Support Ambulances for 30 Day Support
New Haven	CT	$ 2,373,120		12/7/2005	Staffed with fully Licensed Techs Ambulances in support of moving evacuees from hospitals, care centers, etc.
Livermore	CA	$ 2,915,800	Full/Open Competition	9/4/2005	Katrina disaster support CCR/DUNS number required.
Pontiac	MI	$ 322,560	Full/Open Competition	10/3/2005	Katrina disaster support.
Pontiac	MI	$ 322,561	Full/Open Competition	10/14/2005	Katrina disaster support.
Pontiac	MI	$ 691,200	Full/Open Competition	9/4/2005	Katrina disaster relief-Ambulance service in Gulfport, MS
New Haven	CT	$ (122,880)	Not Competed	10/14/2005	Katrina disaster relief-Ambulance service in Gulfport, MS
New Haven	CT	$ 648,960	Not Competed	11/26/2005	Katrina disaster relief-Ambulance service in Gulfport, MS
New Haven	CT	$ 1,148,160	Not Competed	12/16/2005	Katrina disaster relief-Ambulance service in Gulfport, MS
New Haven	CT	$ 1,497,600	Not Competed	11/1/2005	Katrina disaster relief-Ambulance service in Gulfport, MS
New Haven	CT	$ 2,304,000	Not Competed	9/27/2005	Katrina disaster relief-Ambulance service in Gulfport, MS
New Haven	CT	$ 2,304,000	Not Competed	9/28/2005	Katrina disaster relief-Ambulance service in Gulfport, MS

Table 8. Contracts awarded to AMR by FEMA for Hurricane Katrina.

d. Public Concerns

In late-1990, AMR was under public speculation due to complaints from Shelton, CT to Sunnyvale, CA. The privatized company was under the pressure to improve its level of performance and explain specific tragedies involving AMR ambulances that took excessive time in responding to emergency calls. While acknowledging financial strains from a six-year acquisition binge, in which AMR absorbed more than 200 companies to become the nation's largest ambulance firm, they denied compromising their care for patients.[66]

In contrary, AMR made arguing statements that their attempts to save money by laying off hundreds of employees, reducing budgets and renegotiating or dropping 911 contracts, have given the company greater flexibility to improve services. They further argued the enormous size of their nation-wide company makes them susceptible to criticism. AMR claimed that as they consolidated ambulance companies, there were occasional service complaints towards those companies in the past but were then directed against AMR after their takeover. Thus, there was the appearance that one large firm was overall responsible for a series of past problems and complains for the smaller, overtaken companies.[67]

2. Private Firefighters (GF)

Similar to the previous section, the data collected for the second guideline business selection is aimed to help determine the value of having private firefighters supplement municipal response agencies in battling wildfires. The sources accounting for and data collected from GF were dated from late-1990 to mid-2006. Again, GF is an Oregon-based private company that provides multiple contract services, including firefighting crews, portable showers, fire engines and helicopters that assist the U.S. Forest Service and other firefighting government agencies.

a. Emergency Services in Wildfires

Contract firefighting crews are concentrated primarily in the Pacific Northwest, northern California and the Colorado Rocky Mountain region. The Pacific Northwest Wildfire Coordinating Group, administered by the Oregon Department of

[66] Liz Halloran, "Firm Puts Squeeze on 911 Service in Drive for Profits, AMR Whittles Ambulance Standards," *The Hartford Courant*, State of Emergency Second of two parts, 18 JAN 1999

[67] Ibid

Forestry, and the Forest Service's National Firefighter Crew Contract provide the majority of these privatized crews.[68]

Since 1982, GF has been contracted by various federal and state agencies, as well as many private companies, to battle fires throughout the mentioned regions. They performed wildfire suppression services on over 400 incidents, where more than 25% of these incidents were initial attack type.[69] The goal of GF is to provide the various governmental agencies, commercial industries and private landowners with professional, fully-equipped and trained workforces for fire suppression and emergency service crews.

b. Resources and Capabilities

With local offices in the states of Oregon, Idaho and Montana, GF is headquartered in Grants Pass, OR and currently employs 150 full time employees and peak up to 450 in the summer season. The services of this private company include 30 engines, 4 water tenders, 15 Twenty-Person crews, 2 mobile shower units, 3 track engines, 2 potable water trucks and a type 3 helicopter among other resources.

GF has been incorporated in the State of Oregon since 1979 specializing in wildfire suppression, fuels management and emergency services. The following are GF resources that support these specializations:[70]

- Type 2 Crews
- Type 2 IA Crews
- Type 6 4x4 Engines
- Type 4 4x4 Engines – In case of road closures or poor access, these machines are essential for landscape prescribed burns.
- Type 3 Tenders
- Skidgine Track Machines (FMC's)
- Dozer

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[68] Dininny, Shannon. "Report finds Forest Service must strengthen oversight of contract firefighters." SignOnSanDiego.com. 21 MAR 2006. SignOnSanDiego.com. 18 Sep 2006 <http://www.signonsandiego.com/news/nation/20060321-2329-wst-firefightertraining.html>.

[69] "Wildfire Experience." Grayback Forestry, INC. Grayback Forestry, Inc. 18 Sep 2006 <http://www.graybackforestry.com/index.php?option=com_content&task=view&id=24&Itemid=9>.

[70] "Grayback Overview." Grayback Forestry Inc.. Grayback Forestry Inc. 18 Sep 2006 <http://www.graybackforestry.com/index.php?option=com_content&task=view&id=14&Itemid=9%20>.

- 3000 gal. Potable Water Trucks
- Prescribe Burn Teams
- Class C Fellers - Miscellaneous Overhead Positions
- Mobile Shower Units
- Mobile Sinks
- Training Cadre
- Burn Bosses and Overhead Positions

GF uses the Type 6 engines, type 4 engines and tenders to accommodate multiple burns and mop-up operations. All the engines have foam injection systems. The tenders are tactical tenders with 3000 gallon capacity and have foam injection, monitors and high-pressure pumps for added effectiveness. Additionally, GF has 4-wheel drive quads that increase efficiency for packing fuel and mop-up operations on burn projects. One of the 4-wheel drive quads can carry 1,500 pounds of water or fuel. [71]

c. Cost to the Government

GF bills the government between $25 and $30 dollars per hour and per crewmember. On an average of ten-hour days, this totals to about $5K to $6K a day for each private firefighting crew.[72] If all 15 crews are contracted for a major wildfire, the government could pay as high as $90K per ten-hour day. This amount can increase if the work hours exceed ten-hours on any or all of the wildfire suppression days. Additionally, one of GF's fire engines and a three-man crew rents for about $100 per hour.[73] This could cost the government an additional $1K per ten-hour day or even more for extended hours.

On another note, private firefighters do not make as much money during non-fire seasons. "During fire season you learn to put away some money for that slow time," said Grayback crew boss Will Howell, 24, who had only nine days fighting fire in 2004, a low turnout year for wildfires. "You look at the last three years (2001-2003),

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[71] "Engines and Tenders." Grayback Forestry, Inc. Grayback Forestry, Inc. 18 Sep 2006 <http://www.graybackforestry.com/index.php?option=com_content&task=view&id=28&Itemid=9>.

[72] Geoffrey F. Sefal, "Private Firefighters Battle the West's Wildfires." *Reason Public Policy Institute.* 30 OCT 2003. reason.org. 18 Sep 2006 <http://www.rppi.org/privatefirefighters.shtml>.

[73] Ibid

they were incredible seasons. We'd start in May or June. The average season we start in mid-July. That throws you for a loop when you get used to that."[74]

d. Public Concerns

There are separate concerns regarding GF and the private firefighting industry. The GF concern is based on the level of service their crews provide during major burns. In 2003, GF deployed their maximum 15 twenty-person crews to help battle the western wildfires. Although these crews were trained in safety and building fire lines, they were not fielded to dangerous spots like the lead edge of a wildfire.[75] This means that civic firefighting agencies must fill this voided requirement.

The first concern regarding the private firefighting industry is based on a recent report by the inspector-general for the U.S. Forest Service that states illegal immigrants have been fighting fires as privatized crews for several years. About half of the estimated 5,000 private firefighters, based in the Pacific Northwest and contracted by state and federal governments, are immigrants mostly from Mexico.[76] The number of these immigrants working illegally is not disclosed. The state of Oregon, which administers private fire contracts for the Forest Service, imposed tougher rules on companies that employ firefighters, including a requirement that firefighting crew leaders have a working command of English and a formal business location where crew members can assemble.[77]

The other concern is the perception of unethical acts of arson to ensure jobs/contracts for private firefighting crews. Unlike publicly employed municipal firefighters, private contract wild-land firefighters are paid only while they are battling

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[74] "Fire crews thin brush since blazes are few." Wildfires 2004. 7 SEP 2004. MSNBC. 18 Sep 2006 <http://www.msnbc.msn.com/id/5933424/>.

[75] Geoffrey F. Sefal, "Private Firefighters Battle the West's Wildfires." *Reason Public Policy Institute*. 30 OCT 2003. reason.org. 18 Sep 2006 <http://www.rppi.org/privatefirefighters.shtml>.

[76] "Immigrants are forest firefighters." San Diego Union-Tribune. 28 MAY 2006. SignOnSanDiego.com. 18 Sep 2006 <http://www.signonsandiego.com/uniontrib/20060528/news_1n28fire.html>.

[77] Ibid.

fires. Federal policies favoring private firefighters over public agency firefighters have sharply increased both suppression costs in the 1990's and arson incidents.[78]

3. KVA Calculations

Section B of this chapter described that a process is knowledge that is stored in the people and expert systems of a process. The value of this knowledge is not easily understood until a key person is removed from the process or the expert system is removed from the process. If a division has a person that is so experienced in his job that no one else can perform that job in the event that they are not able to come into work for a day. This will hinder the workflow of that division. Single points of failure in an expert system or the personnel in a process highlight how valuable their knowledge or ability is. The value of knowledge or KVA is measured using Learning Time.[79]

This measurement provides a valuable number for the Return on Knowledge (ROK) equation. In order to understand ROK, with respect to LT, knowledge must be defined in a particular way. "It is the know-how required to produce process outputs."[80] Knowledge is proportionate to how long it takes to learn that thing. Learning time is a convenient method for measuring knowledge in a system. In an application to the Navy, a maintenance technician will take three months to qualify or learn the 3M maintenance system and another two months to qualify on the equipment that the technician will be performing maintenance on. The costs associated with the sailor taking five months to qualify to perform maintenance on a piece of equipment is a know quantity. The total cost of the process of qualifying to perform maintenance can be now be defined. Using LT as a surrogate for the return in a ROI problem we can now define this ratio as a ROK.[81] In this example, the ratio would be described as:

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[78] Dr. Timothy Ingalsbee. " Fire Private Firefighters?." NYTimes Archives. 16 JULY 2002. New York Times. 18 Sep 2006 <http://query.nytimes.com/gst/fullpage.html?res=9400E2DC1439F935A25754C0A9649C8B63>.

[79] Glenn R. Cook, Jefferson D. Dyer, "Business Process Reengineering With Knowledge Value Added In Support Of The Department Of The Navy Chief Information Officer" September 2003.

[80] Thomas Housel, Arthur H. Bell, *Measuring and Managing Knowledge*, McGraw-Hill Irwin, 2001.

[81] Glenn R. Cook, Jefferson D. Dyer, "Business Process Reengineering With Knowledge Value Added In Support Of The Department Of The Navy Chief Information Officer" September 2003.

K/C = ROK

K = Knowledge allocated to Revenue[82]

C = total cost

Using *ROK* we can now define value of knowledge in the maintenance process or the *KVA* to the process. This example can be illustrated by applying this procedure to an aggregate or enterprise level and processes are measured in the aggregate.[83] Table 9 demonstrates an aggregate KVA analysis of the Thailand Field Experiment. This table was derived by interviewing the process owners and obtaining average learning-time estimates and a rough estimate of the number of process instructions to complete the process.

From Table 9 column descriptions:

- Subprocess: Identified by the COASTS leadership team
- Number of Employees within each Subprocess
- Times Fired is how many times the Subprocess is completed for each evolution of the greater process
- Nominal Learning Time is how long it would take the average person to learn to do the Subprocess
- IT % is an estimate of % that Subprocess is automated. Used to determine values for column 8.
- Total Learning Time (process instructions) allocated to each Subprocess that is automated. Derived from:

Column 6 x Column 7 + Column 6 = Total Knowledge

- Percentage of Knowledge Allocation (KA): This value is taken from the Total Knowledge per Core Area and its percentage of the Total Knowledge for the Enterprise:

Example: Remote Clients

1680/8382 = 20.04%

- Allocation of Total Revenue to Knowledge or simply the KVA to each core area. This value is derived by taking the total revenue and multiplying it by KA from column 9. This is the numerator in the ROK equation

82 In the case of a DoD application a surrogate for revenue would have to be defined because the DoD does not generate revenue.

83 Thomas Housel, Arthur H. Bell, *Measuring and Managing Knowledge*, McGraw-Hill Irwin, 2001.

- Annual Expense is simply the denominator in the ROK equation.
- ROK per Subprocess.

From this analysis one can see that the Subprocess that has the lowest ROK is the setup of the 802.16 back-haul network. Consequently, the other data in the analysis validates this. It takes the longest amount of time and it is one of the lowest in terms of the percentage of Knowledge embedded in automation. This is an area that would be among the first to study for redesigning. How much of this core area can actually be automated? The overall effect of embedding knowledge in automation or in an IT system creates substantial changes in the way we do business. Unfortunately, not all processes are able to have an IT system embedded into them to improve the process.

Col 1	Col 2	Col 3	Col 4	Col 5	Col 6	Col 7	Col 8	Col 9	Col 10	Col 12	Col 13
Subprocess	# People Involved	Times Fired (per exercise)	Time to Complete (hrs)	Contrac-tor Rate (per hr)	Nominal Learning Time(Hrs)	IT %	TLT (Hrs)	Num-erator	Total Revenue	Total Expense	ROK
802.11 Network											
Set up	6	1	2	$15.00	3	10%	3.30	20	$198	$180	11%
Operate / Maintenance	3	14	1	$15.00	3	50%	4.50	189	$1,894	$630	30%
Take Down	6	1	2	$15.00	3	5%	3.15	19	$189	$180	11%
UAV's											
Launch	3	20	2.00	$20.00	10	90%	19.00	1,140	$11,424	$2,400	48%
Operate / Maintenance	2	20	1.00	$20.00	20	95%	39.00	1,560	$15,634	$800	195%
Recovery	3	20	0.17	$20.00	10	50%	15.00	900	$9,019	$200	451%
Balloons											
Launch	2	20	0.17	$7.50	0.5	0%	0.50	20	$200	$50	40%
Operate / Maintenance	3	20	3.00	$7.50	0.25	0%	0.25	15	$150	$1,350	1%
Recovery	2	20	0.75	$7.50	0.5	0%	0.50	20	$200	$225	9%
TOC											
Set up	6	1	12.00	$15.00	30	10%	33.00	198	$1,984	$1,080	18%
Maintenance	2	14	1.00	$15.00	30	50%	45.00	1,260	$12,627	$420	301%
Take Down	6	1	2.00	$15.00	5	5%	5.25	32	$316	$180	18%
802.16 Back-Haul Network											
Set up	6	1	20.00	$15.00	1	25%	1.25	8	$75	$1,800	0%
Maintenance	1	14	1.00	$15.00	12	50%	18.00	252	$2,525	$210	120%
Take Down	6	1	6.00	$15.00	1	5%	1.05	6	$63	$540	1%
Remote Clients	4	14	5.00	$10.00	10	90%	19.00	1,064	$10,663	$2,800	38%
Network Ops Crew	2	14	8.00	$15.00	40	50%	60.00	1,680	$16,836	$3,360	50%
			67.08					8,382	$84,000	$16,405	51%
Rev Factor for a 2 wk period	$84,000		1 work week is 7 days at 8 hours per day.							Reduction Factor	10.0%

Table 9. KVA Spreadsheet for Thailand Field Exercise

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V. ANALYSIS

A. ANALYSIS OF FINDINGS

1. Field Experiments

a. 2006 COASTS Networks Testing

The COASTS field experiment is an on-going research project based at the NPS. The COASTS field experimentation program supports U.S.Commander Pacific Fleet (COMPACFLT), Joint Interagency Task Force West (JIATF-W), Joint U.S. Military Advisory Group Thailand (JUSMAGTHAI), NPS, Royal Thai Armed Forces (RTARF), and the Thai Department of Research & Development Office (DRDO) science and technology research requirements relating to theater and national security, counter-drug and law enforcement missions, and the Global War On Terror (GWOT)[84].

The COASTS program was designed to integrate the technological expertise of NPS's education and research resources with the potential operational requirements, science and technology of the Royal Thai Air Force (RTAF) using WLAN technologies to fuse and to display information from air and ground sensors to a real-time, multi-level, coalition enabled command and control center. Using COTS technologies, the COASTS research program intended to demonstrate the capacity of coalition communications in an operational context.[85]

The network that was designed for COASTS 2006 supported real-time video, integrated sensors, unmanned aerial vehicles and situational awareness tools from 802.11 a/g mesh and IEEE 802.16 PtMP devices. The backbone link of IEEE 802.16 point-to-point suites was used to link the RTAF Wing 411 communications station to the Royal Thai Army (RTA) Inter-agency Intelligence Fusion Center (IIFC) and to the Mae Ngat Dam area of operations (AO).[86]

At the Mae Ngat Dam AO, various sensors were integrated into this system of systems to create a tactical network architecture. In an IEEE 802.11g mesh

[84] COASTS 2006 CONOPS

[85] Robert Hochstedler, "Implementation of a Modular Fly away Kits (FLAK) for C4ISR in order to counter Asymmetric Threats in the Coalition Riverine and Maritime Theatres." June 2006.

[86] COASTS 2006 CONOPS

WiFi cloud, various sensors and clients were integrated into the network. Unattended ground sensors, IP cameras, UAV's, biometric devices, as well as various client applications and hardware, were enabled through the network.

The COASTS 2006 scenario was intended to test the use of commercial, off-the-shelf (COTS) equipment and procedures that: (1) potentially reduce or mitigate drug trafficking across the Thai-Burma border, (2) provide actionable information (real-time) to local, regional, and strategic level decision-makers, and (3) shorten the sensor-to-shooter cycle.[87] The 802.11 network performed as designed in all aspects and Measures of Effectiveness (MOE) created. The entire AO was under the coverage area of the WiFi cloud during the duration of the field experiment.[88]

(1) UAV's. The UAV's performed with mixed results. The most common problems encountered with using the UAV's during the Thailand Field Experiment was the lack of flight training prior to the deployment and quantity of spare parts for each UAV. Due to funding issues caused because the federal budget was not passed in a timely manner, the UAV's were not purchased until shortly before the Thailand Field Experiment. More training time with the UAV's prior to deployment would have greatly increased the value of the UAV's since the pilots would have had more training time and a better understanding of the spare parts required for prolonged field activity would have been available. Additionally, the UAV's chosen for this year had significant endurance problems. There was no UAV that had a combination of high endurance and high reliability of parts that allowed significant testing of MOE's. The use of UAV's did allow for aerial sensors to be deployed and WAP's to be sent airborne to extend the WiFi cloud.[89]

(2) 802.16. The WiMax network worked as designed. With the exception of the link from the AO to the next tower in the multi-hop trip to Wing 411, all hops were able to transmit at 48 MBps. The link from the AO was only able to transmit

[87] COASTS 2006 CONOPS

[88] COASTS Thailand Field Experiment After Action Report, July 2006.

[89] Ibid

at 6 MBps. With more time and the availability of different antenna configurations, all WiMax hops would be able to transmit at 48 MBps.[90]

(3) Balloons. The balloon payload was constructed using an AN-50M Redline terminal powered by two UBI-2590 batteries with a single 12 dBi omni directional antenna. A Sony PTZ camera was installed for ISR functionality. The payload was connected to a tethered balloon with a lift capacity of 66 lbs. The combined payload weighed 28 lbs. The payload was launched from an island approximately 1.2 miles from the TOC. A 17 dBi 90 degree sector antenna was manually aimed from the TOC to the balloon payload, forming a strong Point to Point connection. The configuration of the aerial 802.16 allowed a connection of greater than 6 MBps throughput to be maintained from launch to the final flight altitude of 4000 feet. At that altitude, the slant range exceeded 1.8 miles, while passing over 36 MBps data throughput. The ISR performance was only limited to the capability of the camera platform. The camera platform was susceptible to movements of the balloon taking the target of interest out of view. The battery life of the UBI-2590s allowed for 6 hours of flight operations. For actual field deployment, the development of longer lasting power sources is needed.[91]

(4) Power Supply. Identified as a single point of failure, an adequate, autonomous power supply is a topic that must be addressed prior to COASTS 2007. The reliance on host nation power sources proved to be problematic. The power that was provided by the host nation was not a sufficient uninterruptible power supply. This caused power surges during testing and the final field experiment. Additionally, power loads at the TOC were not evenly distributed causing down time due to circuit breakers popping. More gas powered generators and Uninterruptible Power Supply (UPS) boxes would solve many of these problems.[92]

b. 2004 GGSN Homeland Security Exercise

The purpose of using the PacketHop solution, as utilized during GGSN's Homeland Security field exercise, as a comparable application to HFNs, if utilized for military HA/DR operations, was to prove whether or not a commercial communication

[90] COASTS Thailand Field Experiment After Action Report, July 2006.

[91] Ibid

[92] Ibid

systems could improve the C2 capabilities for various response agencies. If a comparable system tested successful, then maybe such a C2 solution could benefit the DoD. Various sources have stated the 2004 GGSN Homeland Security field exercise was a successful experiment and that the PacketHop solution was a proven communication system.

> As demonstrated in a live field exercise, PacketHop was able to achieve mobile broadband connectivity across tough terrain – on land and water – and over mobile, infrastructure-less networks for more than ten multi-jurisdiction agencies. This exercise was unquestionably an important milestone in driving the Golden Gate Safety Network closer to its vision to develop and implement a regional communications system that supports a multi-agency response from local, state and federal first responders for day-to-day operations and incident management.[93]
>
> - Michael Griffin, Assistant Chief, CGOES

The tested software solution delivered instantaneous mobile broadband connectivity, providing GGSN agencies with situational awareness in the field. While focusing "efforts on the famed Golden Gate Bridge and surrounding waterways and national parks, dozens of first responders representing 13 multi-jurisdictional agencies were able to instantly communicate and share mission-critical broadband data across diverse devices, difficult terrain and dissimilar networks."[94] The success of the PacketHop solution for the Homeland Security field exercise should be a revelation to the DoD, where commercial technology could allow military activities advanced C2 capabilities in rural HA/DR situations, such as the December 2004 tsunami in Indonesia.

An assumption of this research was that an effective HFN would provide significant benefits to military response units in HA/DR operations. Based on various sources, the PacketHop system tested successful in providing advanced C2 capabilities to multi-agency responders. So if this solution is a comparable application to an "effective HFN," then the DoD should invest in HFN technology and equipment, correct? The answer depends on what requirements actually constitute an effective HFN? For the purposes of this study, an effective HFN is a communication system that provides the

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[93] Michele Spring, Thornton, Laurie. "PacketHop Deploys First Multi-Agency, Mission-Critical, Mobile Broadband Communications Network For Homeland Security." Mayfield Fund - PacketHop. 25 FEB 2004. Mayfield Fund. 18 Sep 2006 <http://www.mayfield.com/newsarticles/packethop022504.htm>.

[94] David Thompson, "Mobile Mesh Networking: Bridge to the Future of Broadband Wireless," *Private Wireless*, Vol. 12, June/July 2004.

necessary C2 capabilities to its users anywhere and anytime. For the most part, the HFN technology tested during the COASTS project were successful. The areas that were not tested successful were due to several factors, including limited timing, delayed funding and late receipt of material prior to deployment; all of which caused limited preparations and pre-deployment testing. This does not necessarily mean the HFN technology is not effective; it could mean that more time and future field tests are required by the COASTS team.

It should be noted that the results of this 2004 field experiment, unlike the 2006 COASTS project, was concluded well before the start of this thesis research. The COASTS project in Thailand was accomplished in May 2006 and there was an uncertainty if the various HFN equipment would test successfully in the field. Then again, the personnel involved in the COASTS project were NPS graduate students in comparison to the skilled, professional responders of the GGSN exercise. Furthermore, the PacketHop system was developed and tested by corporate IT professionals from a reputable corporation, where the equipment being tested for COASTS were experimental systems developed from a variety of sponsoring activities. In regards to the GGSN experiment, PacketHop had a reputation to uphold for providing quality service, using state of the art technology and being a competitive IT business. In a financial analysis intended to identify benefits for the DoD, there is nothing wrong with this. If this is what works, then maybe the DoD should consider this avenue in acquiring advanced C2 systems.

As presented in Chapter III, PacketHop's "Communication System for Public Safety" software is readily available on the market. If the DoD were to invest in this particular system, how much would it cost? First, a scenario must be presented. For this study, it will be a deployable military unit responding to an international CHD. Similar to the size of the deployed COASTS team, ten responders or end-users will be required for this mission. Next, we use the estimated pricing from the company. PacketHop quotes approximately $2K per end-user device and the management console, with Gateway software, will cost about $25K.[95] This totals to an estimate of $45K for

[95] Roland Piquepaille, "An instant and mobile wireless mesh network." Roland Piquepaille's Technology Trends . 24 JUN 2006. primidi.com. 18 Sep 2006 <http://www.primidi.com/2005/08/30.html>.

multicast services, supported by standard IEEE 802.11a/b/g WiFi and 4.9 GHz spectrum with a range of up to 1 km line of sight. Remember, this pricing is just for one system to support one deploying unit. Also, the PacketHop system is not using UAVs, which is a substantial cost for the technology utilized in the COASTS project. Another option for the DoD is to solicit IT companies, like PacketHop, to develop a C2 solution for specifically satisfying military requirements.

2. Financial Methodologies

a. Market Comparables

> One of the frequent sources of legal confusion between cost and value is the tendency of courts, in common with other persons, to think of value as something inherent in the thing valued, rather than as an attitude of persons toward that thing in view of its estimated capacity to perform a service.[96]

In lines with the DoD investing in HFNs for HA/DR purposes, the theory surrounding the value of this investment depends on the future benefits that will accumulate under ownership of the DoD.[97] These future benefits could include, but are not limited to, the frequency commanders quickly attain management control during a crisis situation, improved relations with international response agencies, availability of service when required, cost savings to the government and/or an increased number of lives saved during HA/DR operations. This market comparable analysis will focus on cost comparisons with the guideline business selections and the value of saving lives.

(1) The Cost of Emergency Responses. The market comparable findings in Chapter IV provided cost figures to help link a comparison with the cost of HFNs. For hurricane relief efforts in 2006, FEMA contracted for emergency transportation services, involving AMR, which covers 16 weeks and has a base period cost of $265M. This can be translated to $16.56M per week (which is not to be confused with the $16.56M combined contract value that FEMA awarded to AMR in 2005). The main portion of this contract is for contingency operations, which would only be executed upon task order of the federal government in the case of a presidential declared disaster

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[96] James C. Bonbright, *The Valuation of Property*, Vol. 1, The Michie Company, 1965 [reprint of 1937 edition.], p. 21.

[97] Shannon P. Pratt, Reilly, Robert F. and Schweichs, Robert P., "Valuing a Business", 4th Edition, McGraw-Hill Publishing, 2000, p. 40.

or emergency. According to Rear Admiral Craig Vanderwagen, the Health and Human Services Assistant Secretary for Public Health Emergency Preparedness, "These contracts are an important element in insuring that assets are available to carry out this critical operation." The same can be said for having available assets in the event of a major wildfire. The next cost focus of this analysis is on the costs of private firefighting services.

Based on the service rates provided in Chapter IV, GF bills the government between $25 and $30 dollars per hour and per crewmember, with an average of ten-hour days (about $5K to $6K a day for each private firefighting crew). GF can deploy a maximum of 15 crews for a major wildfire and would cost the government as high as $90K per ten-hour day. Additionally, one of GF's fire engines and a three-man crew rents for about $100 per hour.[98] This could cost the government an additional $1K per ten-hour day or even more for extended hours. So for this analysis, the scenario shall be the government needs to contract GF to battle a major western wildfire that will span for one week or seven ten-hour work days and requires all assets the company has to offer. All assets include 15 twenty-person crews and three fire engines (each including three-person crews). Thus, at the rate of $30 per hour and member, with 15 twenty-person crews and seven ten-hour days, the cost for the crews will be $630K. The additional cost for the 3 fire engines, with a rate of $100 per hour, is $21K. The total cost to the government would be approximately $651K. See Table 10 for the cost-breakdown.

[98] Geoffrey F Sefal,. "Private Firefighters Battle the West's Wildfires." *Reason Public Policy Institute.* 30 OCT 2003. reason.org. 18 Sep 2006 <http://www.rppi.org/privatefirefighters.shtml>.

Crews

Hourly rate per firefighter	$ 30
Firefighters per crew	20
Number of crews requested	15
Number of working days	7
Working hours per day	10
Subtotal	$630,000

Fire Engines

Hourly rate per fire engine	$ 100
Number of fire engines requested	3
Number of working days	7
Working hours per day	10
Subtotal	$ 21,000

Total Cost to the Government

15 Crews	$630,000
3 Fire engines	$ 21,000
Total	$651,000

Table 10. Sample Cost-breakdown for Grayback Forestry Services

This scenario amount of $651K seems inexpensive when compared to the $16.56M weekly value of ambulance services. Remember, this scenario only involves one private company and it is not as big of a company as is AMR, who provide services nationwide. Also, there can be speculation that Katrina relief has received much higher profiles than the western wildfires. Wildfires are almost a routine occurrence in the West, but Katrina made history as one of the worst natural disasters that struck the nation.

The costs for the private ambulance and firefighting services far exceed the costs for the COASTS Project of setting up and running an HFN at a remote location in Thailand. The total cost of the COASTS Project field experiment in Thailand was $308K (see Chapter 3). Furthermore, this cost can easily be reduced by over 25% if the UAV portion of the network is not used. While the costs of setting up an HFN will vary greatly by geographical area, it is evident that establishing an HFN can be considered a cost effective measure to providing relief to a CHD.

In the findings section of this thesis, AMR and GF showed they are both capable and reliable sources for emergency response to crisis situations. In regards to hurricane relief efforts for 2006, AMR and partnering company, ACADIAN, are servicing the city of New Orleans and twelve coastal Louisiana parishes and providing up

to 488 ambulances and para-transit vehicles capable of moving nearly 5,400 special need evacuees.[99] Although a contingent requirement, this capability is of an enormous scale for a private company. The same can be said for wildfires in the west. In 2003, Oregon-based private firefighting companies, such as GF, have been dispatched to help out with wildfires in Colorado, New Mexico, Arizona, Utah and Nevada.[100] The wide-scale capabilities of these two guideline business selections are a good market comparable to HFNs supporting HA/DR operations.

Theoretically, the network cloud of an HFN could be infinitely large, with available bandwidth and operating terrain acting as the only constraints. The HFN utilized by the COASTS team was predetermined to cover a 12 km^2 OA. This area of coverage, again, would cost the government $308K. In comparison to a major wildfire, this 12 km^2 OA coverage could be considered rather small. This could somewhat justify the higher cost of $651K for the supplemental firefighting assistance of GF. Plus, the government tends to pay more when property and homes are in danger from a wildfire. The loss of lives would draw higher public attention than the loss of property, thus, hurricane relief efforts have a higher profile and price tag. Therefore, the government is more willing to spend $16.56M for available assets during hurricane season.

(2) The Value of Saving Lives. Considering the fact that private ambulance service providers and private firefighters share the commonality of being in the business of saving lives, it only seems appropriate for this analysis to measure the value of a human life. But in the life-saving business, is every human being worth the same? Do age, gender, race, religious preference, marital/parental status, educational level, working class and/or citizenship affect the value of a person? Most likely, ambulance personnel, firefighters and military SAR team members may not ask victims too many of these personal questions when attempting to save their lives during a crisis situation. Age and gender, however, may have a personal impact on certain responders, where they prefer to give life-saving priority to babies, children and their mother(s);

[99] "Federal Agencies Collaborate To Aid Special Need Evacuations." FEMA. 18 AUG 2006. FEMA. 18 Sep 2006 <http://www.fema.gov/news/newsrelease.fema?id=29021>.

[100] Geoffrey F Sefal. "Private Firefighters Battle the West's Wildfires." *Reason Public Policy Institute*. 30 OCT 2003. reason.org. 18 Sep 2006 <http://www.rppi.org/privatefirefighters.shtml>.

hence the phrase "women and children first." With this in mind, it is difficult to set one common value to every living person.

According to a 2002 cost-benefit analysis, assigning a monetary value to a living person has not been done in medicine and may be widely regarded as inconsistent with medical ethics.[101] The economics study concluded that human preferences for the provision of health care or other life-saving interventions are probably too complex to be adequately represented by means of a single monetary value expressing the benefits of life-saving. These results served as the starting point to more general discussions surrounding the economic value of activities designed to reduce human mortality.[102] For this financial analysis of HFNs, the activities designed to reduce human mortality are military/government agencies and the market comparables (private ambulance service providers and firefighters).

Now that it has been determined that not all lives can be assigned a single monetary value, is it safe to say that it is just as difficult, if not more, to assign multiple values based various considerations (i.e. – age, gender, race, religious preference, etc.)? If this study were to assign multiple values based on such considerations, it would probably cause controversy or present indications of prejudice. Thus, a monetary value will not be given to a human being. This brings the discussion back to how to measure the value of saving lives. Should the federal/state government invest in contracting ambulance services, firefighters and network system if it means effectively saving lives INCONUS and OUTCONUS? The short answer is yes and is supported by humanitarian ethics.

The humanitarian ethic is about saving the lives of those in the greatest need. There must be respect towards the human dignity of every man, woman and child whose life is or could be devastated by conflict or disaster. Acting on this remains a difficult challenge for humanitarian organizations and all those with a stake in humanitarian crises.[103] Unfortunately, humanitarian aid tends to favor high-profile

[101] Elvik Rune, "Cost-benefit analysis of ambulance and rescue helicopters in Norway: reflections on assigning a monetary value to saving a human life," *National Center for Biotechnology Information*, Institute of Transport Economics, 2002.

[102] Ibid

[103] Cherpitel, Didier. "Putting principles into practice – the key to legitimacy." IFRC. 17 JULY 2003. IFRC. 18 Sep 2006 <www.ifrc.org/docs/news/opinion03/03071701>.

emergencies at the expense of low-profile crisis suffering far from the media or political spotlight. "While countries targeted in the 'War on Terror' have attracted unprecedented levels of humanitarian and reconstruction aid, other – arguably more pressing – crises languish in the shadows."[104] HFNs deployed with the military, via air or sea, could be utilized to improve the effectiveness of saving lives, regardless of high or low-profile.

b. KVA

By measuring the amount of knowledge required for a process and then measuring the cost of acquiring that knowledge, the KVA approach allows you to determine the return on knowledge (ROK). The benefits of the KVA methodology are that by comparing processes, with an ROK value for both processes, it can demonstrate which produces the greater value.[105] This ROK can then be compared to the ROK of a process in similar activity. These two processes can then be compared using their respective ROK values since everything has been reduced to the one common factor of ROK.

In the case of the COASTS Thailand Field Experiment, by examining the ROK from the KVA spreadsheet, Table 9 in Chapter IV, one can see the value of knowledge in each of the subprocesses performed. By concentrating on the subprocesses with the lowest ROK percentages and trying to improve those first, usually through an increase in automation, the overall process of the COASTS Thailand Field Experiment can be improved, incrementally, for very little capital investment. A simple option might be found in the launch and recovery of the balloon subprocesses. If there were a way to automate the process, instead of relying so heavily on manual labor, there would be immediate results for little additional capital. A different approach can be used given the same data from Table 9. If you look for subprocesses that have a high ROK value you can find out what is being done well in those areas to increase productivity or revenue in an area for the entire Enterprise. An example is the maintenance subprocess for the TOC. While the learning time is somewhat higher than most of the other subprocesses for the Thailand Field Experiment, the IT% is higher than most of the other subprocesses. If

[104] Cherpitel, Didier. "Putting principles into practice – the key to legitimacy." IFRC. 17 JULY 2003. IFRC. 18 Sep 2006 <www.ifrc.org/docs/news/opinion03/03071701>.

[105] Thomas Housel, Arthur H. Bell, *Measuring and Managing Knowledge,* McGraw-Hill Irwin, 2001.

there were a way to use some of that IT% on other subprocesses, or capture the knowledge used by the people involved with that subprocess and lower the time to complete another similar subprocess in the entire Enterprise, the overall ROK for the entire Enterprise would increase.

B. IMPLEMENTATION AND MODEL METHODOLOGY

1. Funding and Implementation

In case the DoD decides to invest in HFN systems to support future HA/DR operations, the initiative must go through the Planning, Programming, Budgeting and Execution (PPBE) system before any money is actually spent. The DoD uses the PPBE system to link defense strategy to defense resources.[106] The PPBE system will determine if the C2 initiative becomes a part of the IT budget request submitted to the President's Office of Management and Budget (OMB). If approved at the OMB level, it becomes part of the President's budget and is passed on to Congress. In support of the fiscal year 2007 budget, President George W. Bush requested $30.5 billion for the DoD's IT budget. This budget request is a $100 million increase from the $30.4 billion approved by Congress for 2006.[107] This is an example of how the DoD is emphasizing the need to expand IT solutions to support military transformation.

Upon congressional approval, the C2 initiative officially becomes a budgeted priority for the DoD and the obligation of funding is authorized. The defense allocation, which was determined by the Office of the Secretary of Defense (OSD) and OMB prior to budget submittal, is distributed among the U.S. military services. The concern is whether or not sufficient IT/C2 support funding was properly allocated to the appropriate branch of military service. There tends to be a common belief that the military services have an equal share of defense spending, but this not true. Based on a study of 1980 to 2009 financial figures, the U.S. Navy and Marine Corps use about 30% of the DoD budget, Air Force uses about 30%, Army about 25% and defense-wide agencies about

[106] Julian R. Roberts, Jr., DAU Teaching Note: PPBE Process, December 2003 pg 14 and Lecture Slide for Defense Resource Allocation, MN3331: Principles of Systems Acquisition and Program Management.

[107] Frank Tiboni, "DOD IT Spending Flat for 2007," *Federal Computer Week*, 07 Feb. 2006.

15%.[108] Rather than discussing all the services, this analysis will focus on the operational forces of the Navy and adding the IT/C2 initiative to the fleet's mission capabilities.

The Navy is America's forward deployed force, major deterrence against hostile aggression and emergency response organization to crisis around the world. There are Carrier and/or Expeditionary Strike Groups (CSG/ESGs) stationed or deployed worldwide and these naval forces will most likely be responsible for using HFN systems in HA/DR operations overseas. As the four-star head of the Navy, the Chief of Naval Operations (CNO) would be the decision-maker to implement this HFN capability fleet-wide. The operational chain of command from senior to subordinate is the CNO, the Fleet Commanders (CPF for Pacific Fleet and CLF for Atlantic Fleet), the Type Commanders (i.e.- COMNAVAIRPAC, COMNAVSURFPAC and COMNAVSUBPAC) and the CSG/ESG.

The CSG/ESG would be the user activity of the HFN systems and a designated government contracting agency would be the purchasing activity. The designated Head of Contracting Activity (HCA) for the Navy is Naval Supply Systems Command (NAVSUP), whose primary mission is to provide supply support to the fleet.[109] NAVSUP would assign the lead Fleet and Industrial Supply Center (FISC), COMFISC San Diego, to designate one of their contracting offices to initiate an open-bid solicitation for HA/DR C2 solutions. The contract would be awarded based on best value and the winning bidder's HFN solution must satisfy the criteria for supporting Navy missions involving HA/DR requirements. The acquired HFN systems and components would be received in units of packages or "pack-up kits" (PUKs), with each unit stored inside transportable containers or CONEX boxes. Each PUK would consist of software, hardware and support equipment necessary to provide HFN capabilities for HA/DR field operations. The user activities of these PUKs must ensure sufficient personnel obtain the qualifications for trainer, operator and organizational-level maintenance.

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[108] Philip J. Candreva (Editor), *Practical Financial Management: A Handbook for the Defense Department Financial Manager,* January 2005, pg 25.

[109] "Naval Supply Systems Command." NAVSUP. NAVSUP. 18 Sep 2006 <https://www.navsup.navy.mil/portal/page?_pageid=477,1&_dad=p5star&_schema=P5STAR>.

Upon receiving its share of PUKs, COMPACFLT would then distribute them accordingly to the Type Commanders (TYCOMs). COMNAVSURFPAC (CNSP) would provide PUKs to ESGs that are deployed/deploying and engaged/engaging in the training work-up cycle. USS TARAWA (LHA-1), a naval vessel from ESG-1, would receive a PUK from CNSP prior to their work-up cycle or deployment. As the accountable command, TARAWA is authorized to use the HFN to support HA/DR operations within the Contiguous U.S. (CONUS) or outside (OUTCONUS). Sample scenarios include, but are not limited to, tsunami SAR missions, volcano eruption recovery efforts and emergency responses to major terrorist attacks. Upon completion of the deployment, TARAWA will return the PUK to CNSP who will then distribute to another ESG as appropriate. The PUKs will undergo a cycle of storage, maintenance and issue for years to come.

2. Model Methodology

As mentioned previously in this chapter, if the Navy decided to deploy HFNs in response to HA/DR operations it would do so in the form of a PUK. This PUK should have the following characteristics that were determined during the COASTS 2006 Field Experiments and operational testing.

By definition, a PUK is mobile. This PUK would need to be placed on a ship or cargo plane for rapid deployment in the event of a HA/DR. The gear for the HFN would be packaged and containerized in some form of rugged, mobile shipping container that could be transported from ship to a landing zone by helicopter or LCAC. If the PUK is flown into an OA it would then need to be placed on a truck or transported by helicopter for the “last mile” into the affected area.

Another requirement is that the HFN, in the form of a PUK, would have to be entirely autonomous. Assuming that the HFN is deployed to an area that would have been devastated by some form of disaster, either natural or man made, the infrastructure of the area would not be able to support any requirements of the HFN. Upon deployment, the HFN should be self sustaining; only relying on predetermined logistical help from the deploying ship or air station. This would include fuel for generators, batteries and battery charging facilities, any necessary cables and wires, tools for assembly of the HFN, lodging (tents), water, food, etc.

3. Scalability

Finally, a key concept to an HFN is its scalability. By design, an HFN is infinitely scalable. The only constraints are available bandwidth and the terrain that it is operating in. The HFN used by COASTS for the Thailand Field Experiment would not work for anything much larger than the predetermined 12 km^2 OA. If the Navy were to try and establish an HFN in Indonesia in response to the tsunami of December, 2004, several containers of gear would be needed to support multiple locations spread along hundreds of miles of coastline. There would be a predetermined make-up of each container that would make up a deployed PUK for the HFN. If there was only a small HFN needed, one container could be deployed. If the need was greater than a deployed force could handle, more containers could be flown into the area from CONUS to supplement the PUK that would be deployed from a ship. There would also be a predetermined supply chain and logistical support for the various sizes of the HFNs deployed. This would be broken down into categories such as; the number of personnel needed to support the HFN, bandwidth required by the area affected, total footprint (electric and physical size of the HFN and supporting activity) allowed in the OA, logistical support available while deployed and current technology available.

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VI. CONCLUSION AND RECOMMENDATIONS

A. RESEARCH QUESTIONS

1. What are the Financial Implications Using HFNs in a Remote Or Devastated Operating Area?

The financial costs associated with operating an HFN in a remote or devastated area can be easily determined. By taking the cost of purchasing all of the necessary equipment to build a HFN, adding the cost of maintenance and storage of the purchased equipment plus all of the personnel costs, one can come up with a cost to operate an HFN in any location and to any scale needed. The difficult part of the equation is determining the benefit gained by the implementation of the HFN in the remote or devastated area. Without the HFN, there may be no communications in the affected area. That means that first responders and relief agencies would have no means of communicating with anyone out of shouting distance. The implications of not providing the necessary communication equipment, if available, could result in a greater loss of life due to the limited capabilities of the relief efforts being wasted or misdirected from a lack of C2 that is provided by the use of an HFN. A lack of C2, or communications in general, results in wasted resources and a delay in relief operations due to confusion or lack of proper information. The government money spent on investment in HFNs can be greatly offset by the potential lives saved due to a single HA/DR operation.

2. What Benefits Can Be Gained By Using The Knowledge Value Analysis (KVA) On Hastily-formed Networks (HFNs) In Support Of Humanitarian Assistance/Disaster Relief (HA/DR) Operations?

Knowledge Value Added (KVA) is a viable tool that can be applied to evaluate a process. By measuring the amount of knowledge required for a process and determining the cost of attaining that knowledge, KVA allows you to determine the return on knowledge (ROK). The benefits of KVA are that by comparing processes, both with an ROK value, it can demonstrate which produces the greater value. KVA allows an organization to take its processes and measure them in the same way. By using the input, process, output equation, KVA creates a ration of costs and benefits that can be used as a guideline for process improvement.

Another benefit of KVA is that it can be used to evaluate existing processes or options that are being considered. Once the ROK for the existing process is determined, the ROK of any options under consideration can be compared. If the new options result in a better ROK they should be implemented. The significance of using KVA is that the value gained is visible through the ROK.

3. How Can We Use The Market Comparables Approach To Estimate Or Monetize The Revenue Component To A Similar Civilian Organization (Western Wild Fires, Hurricane Katrina, Etc.)?

The Market Comparables approach is a method of determining a value indication of a business, by using one or more methods that compare the subject to similar businesses, to get a better idea of what the market would pay for the asset(s).[110] As demonstrated in this research, this methodology was used to estimate or monetize the revenue component to two different commercial emergency response activities. Given a major western wildfire scenario, it was learned the government would have to a pay a weekly rate of approximately $651K for supplemental firefighting services and assets from one private company. From an actual 2006 FEMA contract, it was learned the government is willing to pay a weekly rate of approximately $16.56M for emergency transportation services and assets in support of hurricane relief from two private companies.

These two weekly revenues can be compared to the $308K total cost of the COASTS Project field experiment, involving setting up and running an HFN at a remote location in Thailand. The factors that should be considered when analyzing the monetary value of services and assets are the revenue per unit, the OA coverage and unit of output. The following factors were considered and analyzed for this thesis research:

- The revenue per unit was the government costs for the different emergency response services and assets per weekly rate.
- OA coverage:
    - HFN: 12 km^2 remote area.
    - Supplemental firefighters: large-scale wildfire.
    - Emergency medical transport: city of New Orleans and twelve coastal Louisiana parishes.

[110] International Glossary of Business Valuation Terms, June 2001.

- Unit of output:
    - HFN: a mission-critical C2 system, comprised of COTS components, that is interoperable with foreign military partners, operates in adverse weather and terrain conditions and overcomes connectivity issues (bandwidth and technological limitations) with foreign C2 assets.
    - Supplemental firefighters: firefighting services supported by 15 twenty-person crews and three fire engines (each including three-person crews).
    - Emergency medical transport: medical care and evacuation services supported by up to 488 ambulances and para-transit vehicles capable of moving nearly 5,400 special need evacuees within 72 hours.

Given these considerations, as well as the level of profile for Hurricane Katrina, the government cost for investing in HFNs is considered reasonable in comparison to the two Market Comparables and a bargain in comparison to the benefits offered by the C2 system.

4. What Are Equivalent Market Comparables For Financial Implications To The DOD/NGO HA/DR Functions?

The guideline business selections for this research were American Medical Response Inc. (AMR) and Grayback Forestry (GF). AMR is the nation's leading commercial provider of medical transportation and GF is an Oregon-based private firefighting company. In lines with the topic of this thesis, both of these profit-driven businesses provide emergency response services for natural or man-made disaster situations. Commercial-based HFNs and private firefighting and ambulance services all fall under the business of saving lives and providing DoD/NGOs the supplemental support necessary during HA/DR operations.

The concept of HFNs is fairly new and this research is one of the first, if not the first, financial analysis's of HFNs in support of DoD HA/DR operations. There are certainly other equivalent Market Comparables to study in this subject matter and the authors encourage further follow-on market comparable research. To name a few, the following professional businesses are considered prospective candidates for future analysis:

- News reporting teams
- Field journalists
- Hazardous field research (i.e.- Tornado “Chasers”)
- Surveillance teams

Another recommended candidate is the farming industry. Although this business is missing the key element of emergency response, the industry is opening its door to technological innovations to support their large, remote farmland areas. In rural Oregon, a farming community contracted for IT services to provide one of the largest Wi-Fi mesh network clouds in the world, with a coverage of about 700-square-miles that includes the city of Hermiston, four counties and a portion of Washington State.[111] If the government were to invest in HFNs, they would be used in HA/DR operations, where the locations tend to be remote like farmlands or devastated by the disaster.

B. RECOMMENDATIONS

1. Use of Market Comparables and KVA

The Market Comparables approach allows the government to better determine the value of the advanced C2 capabilities offered by HFNs by comparing the values of other emergency response services and assets. Both the DoD practice of the Market Comparables approach and the NPS R&D of HFNs are fairly new. Further Market Comparable research is recommended to give the government a better business perspective of the monetary value of HFNs as used in saving lives, establishing crisis management control capabilities with multiple response agencies and having immediate available assets during HA/DR situations.

In comparison to the Market Comparable approach, KVA has been a hardened financial tool for the DoD. This methodology has been applied to evaluate several DoD processes in order to determine ROK, process improvement guidelines and option comparisons. As further R&D is conducted on HFNs, including future field experiments by the COASTS project or by other activities, there may be a need for additional KVA analysis on the subject.

[111] Rupley, Sebastian. " The Biggest Wi-Fi Cloud of All." PC Magazine. 16 NOV 2005. PC Magazine. 18 Sep 2006 <http://www.pcmag.com/article2/0,1895,1884626,00.asp>.

2. HFNs as a C2 Solution for HA/DR Operations

The HA/DR efforts during Hurricane Katrina tested the limits of the IT that was employed in the disaster response.[112] Several months after the storm battered the Gulf Coast, emergency managers and IT executives were compiling and pondering the IT lessons learned from Katrina.

> When disaster strikes, the response effort relies on an array of IT resources. Command and control systems coordinate rescue operations. Digital imagery and geographic information systems help provide a common operating view of an unfolding situation. Technology also plays a role in reporting incidents, delivering supplies and registering evacuees… As conventional systems shut down [during Katrina], collaboration among emergency response teams, state agencies and federal authorities shifted to a number of improvised systems.[113]

Furthermore, after 9/11, the National Institute of Standards and Technology concluded that "a preponderance of evidence indicates that emergency responder lives were likely lost at the World Trade Center resulting from the lack of timely information-sharing…"[114] The C2 capabilities provided by an effective HFN could have assisted the coordination and collaboration efforts with the various multi-agency response units during Katrina and 9/11.

According to Denning, HFNs offer the ability to form multi-organizational networks rapidly that is crucial to large urgent projects and HA/DR efforts in remote or devastated locations.[115] For this primary reason, as well as all the mentioned benefits throughout this thesis, there is a governmental need for a financial analysis on HFNs. This research alone cannot answer the many anticipated questions the DoD may have on the financial matters of HFN investments. Analyzing the financial aspects of HFNs is an interesting but broad subject area of research. Many topics from within this thesis provide areas for additional research.

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[112] Moore, John. "Hurricane Katrina exposed the strengths and weaknesses of emergency management systems needed for homeland security." FCW.com. 5 DEC 2005. Federal Computer Week. 18 Sep 2006 <www.fcw.com/article91602-12-05-05-Print>.

[113] Ibid

[114] National Institute of Standards and Technology, *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: The Emergency Response Operation*, Washington, D.C., 2005, p. 174.

[115] Peter J. Denning, "The Profession of IT," *Communications of the ACM*, Vol. 49, No. 4, APR 2006

The authors of this thesis encourage future follow-on research and analysis on the financial implications of HFNs in support of HA/DR operations. Understanding how to create, finance and establish HFNs is one of the most challenging parts of modern networking. HFNs are "about how a network, its people and its equipment, may function efficiently under extreme stress."[116] This study can provide limited financial and technical guidance for those who are in an organization, or one day may be a part of an organization, that responds in an HFN.

3. Implications of Future Research

Since it is near impossible to anticipate what will happen with HFN technology five to ten years from now, the information from this study will need to be revisited frequently to guarantee its relevance. That being said, the following are the authors' recommended future research and follow-on topics that are directed at maintaining the relevance of the financial analysis of HFNs:

- Funding Civil-Military Communication Systems
- Training the Skill of Improvisation to Support HFNs
- Financial Analysis of HFNs in HA/DR operations using the Real Options Methodology
- Using HFNs to enhance the C2 capabilities of Military Operations with foreign militaries

[116] Peter J. Denning, "The Profession of IT," *Communications of the ACM*, Vol. 49, No. 4, APR 2006

LIST OF REFERENCES

Ackerly, Katie. "Hurricane Katrina, Response and Recovery." GAP - Government Affairs Program. 6 JUNE 2006. AGI - American Geological Institute. 18 Sep 2006 <http://www.agiweb.org/gap/legis109/katrina.html>.

Acosta, Francis. " Why Meshdynamics Structured MeshTM is Different." Mesh Dynamics. Mesh Dynamics. 18 Sep 2006 <http://www.meshdynamics.com/WhyStructuredMesh.html>.

Bonbright, James C., *The Valuation of Property*, Vol. 1, The Michie Company, 1965 [reprint of 1937 edition.], p. 21.

Burke, Frank M., Jr., *Valuation and Valuation Planning for Closely Held Business*, 1981, pg 49.

Candreva, Philip J. (Editor), *Practical Financial Management: A Handbook for the Defense Department Financial Manager*, January 2005, p 25.

Cherpitel, Didier. "Putting principles into practice – the key to legitimacy." IFRC. 17 JULY 2003. IFRC. 18 Sep 2006 <www.ifrc.org/docs/news/opinion03/03071701>.

Clanon, Jeff . "SoL's Hastily Formed Networks Project." Society for Organizational Learning. Society for Organizational Learning. 18 Sep 2006 <www.solonline.org>.

Cook, Glenn R., Dyer, Jefferson D., "Business Process Reengineering With Knowledge Value Added In Support Of The Department Of The Navy Chief Information Officer" September 2003.

Cramer, Myron. "Measuring the Value of Information." Atlanta, GA: Georgia Tech Research Institute. <http://iw.gtri.gatech.edu> [20 July 2005]

Denning, Peter J., "The Profession of IT," *Communications of the ACM*, Vol. 49, No. 4, April 2006.

Dininny, Shannon, "Report finds Forest Service must strengthen oversight of contract firefighters," *San Diego Union Tribune*, 21 MAR 2006

Ehlert, James, March 2006, Coast Concept of Operations

Fisher, Neal, "Valuation: Theory vs Practice." Miller, Cooper & Co., LTD. 23 MAY 2006 <www.millercooper.com/lib_valuation5.htm>.

Ford, Todd D.; Hogan, James L.; Perry, Michael W. *Communication During Complex Humanitarian Emergencies: Using Technology to Bridge the Gap.* Master Thesis. Naval Postgraduate School. September 2002

Griffith, Eric. "Instant Connection for First Responders." Wi-Fi Planet. 22 AUG 2005. Wi-Fi Planet. 18 Sep 2006 <http://www.wi-fiplanet.com/news/article.php/3529111>.

Griffith, Eric. "Meshing with Homeland." Wi-Fi Planet. 26 FEB 2004. Wi-Fi Planet. 18 Sep 2006 <http://www.wi-fiplanet.com/news/article.php/3318551>.

Guide for Managing Information Technology (IT) as an Investment and Measuring Performance. Version 1.0. Arlington, Virginia: Vector Research Inc., 10 February 1997.

Halloran, Liz, "Firm Puts Squeeze on 911 Service in Drive for Profits, AMR Whittles Ambulance Standards," *The Hartford Courant*, State of Emergency Second of two parts, 18 JAN 1999

Hayes-Roth, Rick, Dr., Hyper-Beings: How Intelligent Organizations Attain Supremacy through Information Superiority, 10-11, 2003.

Hileman, Deborah, "American Medical Response Sends Ambulances, Medics to Mississippi Coast," AMR News, 31 AUG 2005,

Hileman, Deborah. "Hurricane Katrina Fast Facts." AMR News. AMR. 18 Sep 2006 <http://www.amr.net/news/releases/Katrina.asp>.

Hochstedler, Robert, "Implementation of a Modular Fly away Kits (FLAK) for C4ISR in order to counter Asymmetric Threats in the Coalition Riverine and Maritime Theatres." June 2006.

Housel Thomas, . "KVA." Naval Postgraduate School. Monterey, CA. 15 FEB 2006.

Housel, Thomas J., and Bell, Arthur H., *Measuring and Managing Knowledge*, McGraw-Hill Irwin, 2001.

Housel, T. El Sawy, O., Zhong, J., and Rodgers, W. "Models for Measuring the Return on Information Technology: A Proof of Concept Demonstration." 22nd International Conference on Information Systems. December 2001.

Ingalsbee, Timothy, Dr. " Fire Private Firefighters?." NYTimes Archives. 16 JULY 2002. New York Times. 18 Sep 2006.

Kantor, Andrew, "In the communication age, connection is everything," *USA Today*, 08 DEC 2005.

Lancaster, David D. *Developing a FLy-Away-Kit (FLAK) to Support Hastily Formed Networks (HFN) for Humanitarian Assistance and Disaster Relief (HA/DR).* Master Thesis. Naval Postgraduate School. June 2005.

Liddle, David, "Mobile Adhoc Mesh Public Safety Applications of Adaptive Radios," PacketHop Powerpoint Presentation, PacketHopInc., 2004.

Malykhina, Elena, "An Instant and Mobile Wireless Mesh Network," *NewsFactor Network*, 29 AUG 2005.

Moore, Douglas. "AMR is Awarded FEMA Contract for Disaster Response in New Orleans and South Louisiana." CNBC Money. 21 AUG 2006. CNBC. 18 Sep 2006 <http://news.moneycentral.msn.com/ticker/article.asp?Feed=BW&Date=20060821&ID=5961309&Symbol=US:EMS>.

Moore, John. "Hurricane Katrina exposed the strengths and weaknesses of emergency management systems needed for homeland security." FCW.com. 5 DEC 2005. Federal Computer Week. 18 Sep 2006 <www.fcw.com/article91602-12-05-05-Print>.

Piquepaille, Roland. "An instant and mobile wireless mesh network." Roland Piquepaille's Technology Trends . 24 JUN 2006. primidi.com. 18 Sep 2006 <http://www.primidi.com/2005/08/30.html>.

Pratt, Shannon P., Reilly, Robert F. and Schweichs, Robert P., "Valuing a Business", 4th Edition, McGraw-Hill Publishing, 2000, pp 45-47, 232.

Roberts, Julian R., Jr., DAU Teaching Note: PPBE Process, December 2003 pg 14 and Lecture Slide for Defense Resource Allocation, MN3331: Principles of Systems Acquisition and Program Management.

Rune, Elvik, "Cost-benefit analysis of ambulance and rescue helicopters in Norway: reflections on assigning a monetary value to saving a human life," *National Center for Biotechnology Information*, Institute of Transport Economics, 2002.

Runge, Chad. "Disaster Relief Efforts & Information." Hastily Built Network to Deploy to Gulf Region . 09 SEP 2005. Naval Postgraduate School. 18 Sep 2006 <http://www.nps.navy.mil/DisasterRelief/Katrina/news/20050909.htm>.

Rupley, Sebastian. " The Biggest Wi-Fi Cloud of All." PC Magazine. 16 NOV 2005. PC Magazine. 18 Sep 2006 <http://www.pcmag.com/article2/0,1895,1884626,00.asp>.

Sefal, Geoffrey F. "Private Firefighters Battle the West's Wildfires." reason.org. 30 OCT 2003. reason.org. 18 Sep 2006 <http://www.rppi.org/privatefirefighters.shtml>.

Spring, Michele, Thornton, Laurie. "PacketHop Deploys First Multi-Agency, Mission-Critical, Mobile Broadband Communications Network For Homeland Security."

Mayfield Fund - PacketHop. 25 FEB 2004. Mayfield Fund. 18 Sep 2006 <http://www.mayfield.com/newsarticles/packethop022504.htm>.

Thompson, David, “Mobile Mesh Networking: Bridge to the Future of Broadband Wireless,” *Private Wireless*, Vol. 12, June/July 2004.

Tiboni, Frank, “DOD IT Spending Flat for 2007,” *Federal Computer Week*, 07 Feb. 2006.

"About AMR." AMR, About AMR. AMR. 18 Sep 2006 <http://www.amr.net/company/index.asp>.

"Ambulance." wikipedia. wikipedia. 18 Sep 2006 <http://en.wikipedia.org/wiki/Ambulance#Private_ambulance>.

"Archived news extracts about GPS and Wireless Technologies 2005." GPS-practice-and-fun. 11 JUL 2005. GPS/Wireless. 18 Sep 2006 <http://www.gps-practice-and-fun.com/archived-gps-wireless-news-2005.html>.

"California's Emergency Medical Response Systems in Crisis." Medical News Today. 27 FEB 2005. Medical News Today. 18 Sep 2006 <http://www.medicalnewstoday.com/medicalnews.php?newsid=20420>.

COASTS 2006 CONOPS

COASTS Point Sur Field Experiment After Action Report, December 2005.

COASTS Thailand Field Experiment After Action Report, July 2006.

"The Costs of Katrina: Rebuilding the Gulf." Taxpayers for Common Sense. Taxpayers for Common Sense. 18 Sep 2006 <www.taxpayer.net/budget/katrinaspending/tcscontractslist.pdf>.

DHS Comprehensive Reviews Fact Sheet document, “Comprehensive Reviews Yield Effective Practices for Homeland Security,” U.S. Department of Homeland Security, 30 MAR 2006.

"Engines and Tenders." Grayback Forestry, Inc. Grayback Forestry, Inc. 18 Sep 2006 <http://www.graybackforestry.com/index.php?option=com_content&task=view&id=28&Itemid=9>.

"Federal Agencies Collaborate To Aid Special Need Evacuations." FEMA. 18 AUG 2006. FEMA. 18 Sep 2006 <http://www.fema.gov/news/newsrelease.fema?id=29021>.

"Fire crews thin brush since blazes are few." Wildfires 2004. 7 SEP 2004. MSNBC. 18 Sep 2006 <http://www.msnbc.msn.com/id/5933424/>.

"Firefighting Worldwide." wikipedia. wikipedia. 18 Sep 2006 <http://en.wikipedia.org/wiki/Firefighting_worldwide>.

Foreword from Secretary of Defense, Donald H. Rumsfeld, *Transformation Planning Guidance*, 2003.

"The Free Market Approach." OSD Comptroller iCenter. DoD Office of the Secretary of Defense. 18 Sep 2006 <http://www.dod.mil/comptroller/icenter/dwcf/freemarket.htm>.

"Grayback Overview." Grayback Forestry Inc.. Grayback Forestry Inc. 18 Sep 2006 <http://www.graybackforestry.com/index.php?option=com_content&task=view&id=14&Itemid=9%20>.

"The History of AMR." AMR. AMR History. 18 Sep 2006 <http://www.amr.net/company/history.asp>.

"Immigrants are forest firefighters." San Diego Union-Tribune. 28 MAY 2006. SignOnSanDiego.com. 18 Sep 2006 <http://www.signonsandiego.com/uniontrib/20060528/news_1n28fire.html>.

International Glossary of Business Valuation Terms, June 2001.

"Knowledge Value-Added (KVA) Methodology." IEC On-Line Education. 2005. International Engineering Consortium. 18 Sep 2006 <http://www.iec.org/online/tutorials/kva/topic01.html>.

"Mobile-Mesh Communication Systems." PacketHop Communication without limitation. PacketHop. 18 Sep 2006 <http://www.packethop.com/public_safety>.

National Institute of Standards and Technology, *Federal Building and Fire Safety Investigation of the World Trade Center Disaster: The Emergency Response Operation*, Washington, D.C., 2005, p. 174.

"Naval Supply Systems Command." NAVSUP. NAVSUP. 18 Sep 2006 <https://www.navsup.navy.mil/portal/page?_pageid=477,1&_dad=p5star&_schema=P5STAR>.

"Private ambulance companies." wikipedia. wikipedia. 18 Sep 2006 <http://en.wikipedia.org/wiki/Ambulance#Private_ambulance_companies>.

"Report shows private firefighters poorly trained." KOMO 4 News. 18 SEP 2006. Seattle Times. 18 Sep 2006 <http://ww3.komotv.com/Global/story.asp?S=4667493>.

Transformation Planning Guidance, United States Department of Defense [US DoD], 2003.

“Urban Meshed Warrior,” Daily Wireless, 25 FEB 2004, www.dailywireless.org/modules.php?name=News&file=article&sid=2130&src=rss10

"Wildfire Experience." Grayback Forestry, INC. Grayback Forestry, Inc. 18 Sep 2006 <http://www.graybackforestry.com/index.php?option=com_content&task=view&id=24&Itemid=9>.

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